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MAY, 1954

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Vol. 26 No. 2

PUBLISHED
WAYNE UNIVERSITY PRESS,

HUMAN BIOLOGY

a record of research

FOUNDED BY RAYMOND PEARL

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HUMAN BIOLOGY is published quarterly by Wayne University Press, Detroit 1, Michigan, U. S. A. The advance subscription price is $5.00 a year (foreign postage 35 cents; Canadian 15 cents). Single current issues are $2.00, plus postage.

Subscribers should notify the publishers of change in address at least two weeks before publication of the issue with which the change is to take effect. No claim for non-receipt of an issue will be entertained unless made immediately upon receipt of the next succeeding issue.

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WAYNE UNIVERSITY PRESS, *Publishers*

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CULTURAL FACTORS AFFECTING THE STUDY OF HUMAN BIOLOGY

THE existence of a field called human biology and the need for a distinct journal bearing this name, may be justified in one of two ways. Attention may be drawn to the unique taxonomic position of man. Alternatively, attention may be directed to the behavior of man, which differs markedly from group to group. The first justification rests on biological grounds. The second justification takes cognizance of the existence of culture.

As to man's unique position in nature, the magnitude of the biological differences now seems less and less. The bipedal gait, and the upright posture, no longer can be claimed as exclusively human. Relative hairlessness turns out to be a characteristic shared by other anthropoids, and in this respect they may occasionally surpass man. In motor development the young chimpanzee is more than superficially like the human infant. And it turns out that other anthropoids can use symbols, invent tools, and solve abstract problems. Anatomically, biochemically, and physiologically, it becomes increasingly difficult to demonstrate in what respects man is completely unique. Yet it is still true that we can not investigate human biology in quite the same fashion that we

investigate the biology of some other species, because of the cultural factor.

For most species, we can assume randomness of mating. True, animals do have preferences (in this respect too they are "human") and the sexual stimulus value of females exhibits a wide range of variation. But such preferences are not systematized within a breeding population. Animals do not seek prior information about prospective mating partners, nor do they eschew potential spouses because of consanguinity, voluntary affiliations, or political or religious beliefs. In man, however, the existence of traditions directing the choice of mates, or limiting the choice to a particular individual out of many, is so common that truly random mating may be considered unlikely for all but the smallest and least complex groups. Or, to put it differently, in what other animal does a railroad track serve as an effective barrier to gene flow? In what other species may the mating pattern involve marriage to two sisters, or a woman and her daughter?

For most animal forms it is possible to observe the dietary range and therefore to make certain inferences as to their metabolic requirements. In some cases, an extremely limited dietary range gives immediate indication of a metabolic peculiarity. But in man, any attempt to estimate the dietary range from the food habits of a particular group runs into early failure. For food prohibitions, learned eating preferences, and culturally-defined limits on what is considered edible, limit the individual to a fraction of what is actually palatable, reasonably nutritious, and satisfying. Not infrequently it is found that a weed (a plant considered inedible) is a superior source of nutrients, while a time-honored cultivated plant proves hardly worth the boiling.

Similar problems arise in studying fecundity, fertility, or their prelude sexual activity. For here biology is thoroughly submerged by cultural practices. The birth rate, crude or corrected, is at best only a partial indication of the reproductive potential. It is affected by the mean age of marriage, the extent of sexual activity (including ritual taboos) and what the members of the group choose to do about conception. And, in discussing sexual activity, the extent of cultural influences can hardly be overestimated. There are marked differences in what is considered to be a "normal" coital frequency. Moreover, sexual behavior may be altered by changes within the culture, or even by disseminating statistical information about sexual behavior! To find a parallel in any other species would be difficult indeed.

While the problem of obtaining culture-free biological data on human beings is difficult enough, the problem of applying data (known to be culture-influenced) for human betterment, is especially hazardous. In our desire to improve the nutritional status of other peoples, we attempt to instill our own dietary practices. Yet there is little evidence at present that three meals a day, as contrasted with two or one, is a physiological necessity rather than just a particular way of our own.

And there are times when physiological data seem strongly culture bound. To an American, British insistence that the custom of mid-afternoon tea is the natural result of the afternoon fall in blood sugar sounds like a rationalization. It is legitimate to enquire whether comparable changes in blood sugar also occur in subjects not habituated to the taking of tea, and whether the pattern demonstrated in Britain may not be an anticipatory response rather than a portent of impeding hypoglycemia.

These various examples serve to demonstrate the extent to which cultural practices intrude into the study of human biology, making it quite different from the study of any other species. They also indicate the kind of information that the human biologist needs to have, above and beyond the information ordinarily required in biological research.

CULTURAL FACTORS AND PROBLEMS IN HUMAN GENETICS

The extent to which cultural factors have to be reckoned with is extremely apparent in human genetics, especially population genetics, as compared to family-line or pedigree analyses. In shifting from rare, usually pathological traits, to common and non-pathological characteristics, the easily defined lineage has been replaced by the more nebulous "population." And this latter unit is by no means identical with the horde or tribe on the one hand, or the city or state on the other.

Suppose that we are interested in the population frequencies for p, q and r and are given a small group and have reasonable evidence that the group is endogamous, not divided into moieties, and not overly weighted by a single lineage, the observed frequencies for the group are in fact population frequencies. (We assume that the total group is represented, or alternatively that the serologist avoided typing his informant's lineage exclusively.) But how about a larger group, made up of two, four or more distinct breeding populations? Firstly, does the serologist know of the existence of these sympatric yet reproductively

isolated populations? Secondly, how does he go about identifying the breeding group to which each subject belongs?

Further examples of the same situation exist in every large city, wherein a dozen or more breeding groups are partially concealed by uniformities of language and dress. Cities are economic units to be sure; they are also political units and demographic units. But, as in Boston or Vienna, cities are not populations in the genetical sense. The distinct breeding groups may be markedly different in gene frequencies. In extreme cases, as in Indian cities, divisions of a single hereditary occupational class (caste) may differ as much as Negro and White in Baton Rouge, Louisiana. Under these circumstances data on the blood groups of New York City, or the blood groups of Rochester, New York, need not provide information on "population" genetics, useful though they are in many other ways.

For obvious reasons, hospital patients have been a favorite source of genetical information. They are at least temporarily incarcerated, they expect to be questioned and bled, and (assuming that disease is no respecter of persons) they should be relatively unselected. But hospital patients are not random representatives despite the anonymity provided by a hospital gown.

Out-patients, and to a lesser extent, ward patients come from the hospital's immediate vicinity and thus reflect the composition of the adjacent districts. If the district is Irish, so will be the out-patients, even though the hospital bears a Hebrew name. In Boston the Massachusetts General Hospital, located in a region of cold-water flats, includes a disproportionate number of Italian patients, though the more exclusive Phillips House attracts the expensively sick from all the world. The Peter Bent Brigham, on the other hand, draws more heavily from the Jewish quarters of Brookline and Roxbury. Such differences in out-patient origin may also be observed in the hospitals of New York City or London. Under these circumstances, estimates of gene frequencies based on out-patients alone may have a limited value, while attempts to show race-associated disease predisposition may be prejudiced by the simple matter of just where in a city a hospital is located.

The fact that immigrants settle in the least expensive section of a city, close to fellow nationals, is a boon to the human geneticist. Locating one Maloof in the phone book locates an entire Syrian community, just as locating one Slovene provides the entré to many. Because migrations often take place on a family-wide, community-wide, or city-wide basis,

it is possible to sample the genetic composition of an Albanian village in Boston, or an Armenian province in Providence; to locate Iroquois Indians, contact structural-steel workers in Rochester!

But the very facts that migrations do take place on a family-line basis (not as isolated individuals of either sex) and religious conversions are not distributed at random, make more difficult such tasks as the demonstration of "genetic drift" in man. Were migration an individual matter, or the joining of religious isolates restricted only to sexually mature but unmarried males and females, demonstrating drift would be reasonably simple. All that would be necessary would be the comparison of gene frequencies in the migrant group or in the descendants of the original converts, with gene frequencies in the parental population (or their descendants). But the simple facts that people do not migrate at random, unrelated men and women of breeding age are not suddenly cut off from their tribe, and randomly sampled men and women do not run off and join a religious commmunity, provide a serious problem for those interested in demonstrating drift. For the migrants most likely included families, the adults, cut off by flood or earthquake probably were related, while the sect leaders probably converted entire families, and related families at that. Under these circumstances it is legitimate to ask whether the prerequisites for the successful demonstration of genetic drift in man will ever be met.

It is evident, then, that the study of human genetics is thoroughly complicated by the existence of culture. Statistical corrections have to be made for polygamy, polygyny, and cross-cousin marriage, to say nothing of the sororate, the levirate and marrying one's deceased wife's mother. Because the population unit-of-study is not identical with the township, city or community, the geneticist must have prior information on what breeding groups actually exist. In dealing with hospital patients, the notion has to be suppressed that in their nightgowns they are a random sample of anything. And the systematics of human behavior practically provide a guarantee against the possibility that any group united by binding ties will be composed of "randomly" selected men and women. Therefore conditions suitable for the demonstration of drift may be extremely difficult to document in man.

CULTURAL FACTORS AND THE STUDY OF HUMAN GROWTH

In contrast to human genetics, where the complexities of mating systems only recently have begun to attract interest, research in human growth has been characterized by a formal appreciation of cultural differences. In fact many studies have been specifically designed to show the extent of cultural influences. The growth of children of similar stock, but under different cultural conditions, has been compared. The sizes of children in different cities have been contrasted. Rural-urban differences have been investigated and social class has been given more attention in growth studies than in any other area of human biology.

But if students of growth have been aware of cultural differences in the abstract, they have failed to be specific. Logically, and perhaps correctly, group divergences in body size or in the rate of growth (apart from those differences manifestly racial in nature) have been attributed to dietary differences. Unfortunately, dietary studies have rarely accompanied the measuring of stature, and the taking of weight, so that the prime variable remains unstudied.

Further, the existence of specific cultural practices bearing upon the growth rate has been given little attention. The possibility that child growth is less rapid where voluntary activity is greater has not been considered. Nor has the mean temperature of the home been given attention, despite the close relationship between temperature and involuntary activity.

The middle class American child, reared by moderately authoritarian and relatively apprehensive parents (by global standards), is protected from over-exertion. His play periods are timed, naps are enforced, and care is taken to assure uninterrupted slumber. Children of the lower classes, cn the other hand, are treated in more permissive fashion, with less emphasis on rest and a more lenient attitude toward bed-time. Therefore, though the caloric intake may be comparable in the two groups, the caloric expenditure is not. And the difference, caloric intake minus caloric expenditure, represents the energy reserve available for tissue maintenance and growth.

In some cultures even less attention is paid to rest. An African settlement or a Balinese village may operate on a 24–hour schedule with events of interest all the while. There, uninterrupted sleep may be a rarity for the children, with cat-naps alternating with participation

in the village night-life. Such practices further increase the energy expenditure, leaving a minimal reserve for the process of growth.

Besides, the temperature of the home may play an important role. Energy metabolism and temperature are inversely related. As the temperature falls, considerable energy is utilized in maintaining body temperature and in insensible shivering. Under these circumstances the high October-through-April temperatures of the American household (which distress visiting Europeans so markedly) may have a hothouse effect on the children allowing the maximum usage of the energy intake for growth.

In addition to these systematic differences in child-rearing practices, which may bear upon energy metabolism, we should note those practices affecting one sex alone. In many parts of the world, women eat apart from the men, girls get the soup while boys get the meat. Or both sexes may eat with the women until puberty, with the boys transferring to the men's table thereafter. Boy babies may be suckled longer (to make them strong), or weaned earlier (to make them independent). Such child-rearing practices may be expected to have a marked effect upon stature and weight, producing growth curves markedly different from those customarily encountered.

It is not sufficient, then, to be aware of cultural differences in the abstract: rather it is necessary to know enough of the cultural practices to relate them to the growth phenomena under investigation.

CULTURE AND HUMAN PERFORMANCE

We have left until last the extremes of human performance and the physiologic concommitants of race. To what extent do cultural practices influence cold-tolerance, heat-tolerance, and load carrying? To what extent have we evidence that races differ in performance levels with the cultural variable ruled out?

In view of the variations in cultural conditioning, it is not unlikely that properly selected "natives" would upset the best laboratory data we have. Malayan pearl divers routinely exceed our breath-holding records. Andean miners mock our need for pressurized planes. The Ona of South America exist in an unclothed state under conditions that would hospitalize Americans for "exposure." Merchants in Mecca, and donkey drivers too, keep busy at a temperature designed to melt myelin. And Korean porters tote ammunition boxes amazingly heavy in respect

to their body weight. While it is not culture itself but extensive physical conditioning that makes such feats possible, it is in particular cultural contexts that they are deemed attainable. As a member of a culture, each individual gains a knowledge of what the extremes of performance are supposed to be and we may presume that under test conditions he reports the limits of his endurance accordingly.

As to racial differences, numerical data are scanty, though hearsay reports are numerous. Eskimo are supposed to have more resistance to cold, an expectable consequence of over 40 centuries of cold selection. Negroes are supposed to exhibit higher heat tolerance, again a not unexpected finding in view of their adaptive zone.

But the available data are far from being culture-free. The most recent tests contrasted Point Barrow Eskimo with whites recently arrived in the arctic. In proving Negro superiority under hot and humid conditions, northern white college students were pitted against southern Negro sharecroppers. It still remains to be seen how real the differences are with the variables of culture removed.

Under these circumstances it would seem that the range of human capacities, including cold-tolerance, heat-tolerance, and load-carrying will have to be reinvestigated with more adequate attention to the cultural factor. As with studies involving nutrition, genetics, or human growth, these more coldly physiological aspects of human biology can not be investigated as if the subjects lived in a cultural vacuum, up to the time they were enlisted as "volunteers" for research.

It is the purpose of this article to show how cultural factors intrude into the study of human biology. Man can not be treated just as a large primate, amenable to the methods and techniques of mammalian biology. The investigation of human biology demands precautions, research methods, and fore-knowledge unparalleled for any other species. And many of the problems in human biology are themselves unique, holding for one human group and not for another.

For some studies, a knowledge of social structure and mating systems may be a prime necessity. For others, detailed information on the dietary habits and techniques of food preparation may be equally important. Still other studies may demand information on contraceptive techniques and local beliefs concerning reproduction. Yet others may hinge on knowing at what age infants are allowed to roam or what restrictions are imposed on pregnant women. Such knowledge is not ordinarily a part of biological research, nor is it needed for a genetically constant

organism, on a standardized diet, reared under laboratory conditions. But for man, with culture a principal variable, information of this sort is an indispensable prerequisite in research.

The existence of the field of human biology, and the need for a journal bearing this name, derive ample justification from the simple fact that the organism in question, man, possesses the quality we call culture.

STANLEY MARION GARN
Fels Research Institute
Yellow Springs, Ohio

PATTERNS OF GROWTH OF THE SKULL AS REVEALED BY VITAL STAINING *

BY MELVYN J. BAER
The Merrill-Palmer School
Detroit, Michigan

INTRODUCTION

THE purpose of the study here reported was to determine the processes of bone growth influencing the form of the skull of the rat in order to better understand these processes in mammals in general and in man in particular. The experimental technique of staining the growing bone with alizarin red S was used (1) to reveal the specific sites and modes of growth resulting in an increase in the size of the skull, and (2) to assess the effects of differential growth at these sites in modifying cranial form. The determination of the anatomical factors governing the relationships of the cranial vault, the cranial base, and the face is believed to have implication for the interpretation of morphological differences among related species and for the analysis of changing form and proportion during the ontogenetic development of the mammalian skull.

The nature of the biological mechanisms affecting changes in cranial form is of particular significance for physical anthropology, which is concerned with the analysis of the phylogenetic development of the human skull. Investigators using the techniques of comparative anatomy and anthropometry have described an evolutionary trend among fossil and modern human forms resulting in a general increase in the size of the brain case and reduction in the size of the face and the cranial

* Aided by a grant from the Wenner-Gren Foundation for Anthropological Research. This article reports the study which the author presented as his doctoral dissertation in anthropology to the University of Chicago.

architecture (supraorbital ridges, temporal lines, and nuchal crests). It has generally been conceded that the differences in form and proportion found among fossil and living groups are due to changes in relative rates of growth, but the actual processes have remained obscure, and the differences have been explained largely by inferences drawn from the descriptive data. For example, Weidenreich ('41, '45), on the basis of comparisons of different species of dogs, apes, and men, contends that "the cerebral predominance that characterizes the skulls of dwarf forms and man not only determines the special shape of the brain case proper, but also the size and arrangement of the facial parts and, in connection therewith, the development of the superstructures of the cranium" ('41, p. 378). According to this interpretation, then, the skull is a single system of growth in which the size of the brain alone determines cranial form.

It is significant that Weidenreich uses data drawn from pathology, such as the cranial form of microcephalic skulls, to support his interpretation. De Beer ('37, p. 485) also refers to microcephaly in his explanation of the development of the skull, and arrives at a quite different conclusion concerning the relationship of the vault, face, and cranial base. "It is therefore clear," he states, "from these micocephalic skulls that the dermal bones of the brain case (frontal, parietal, squamosal, supraoccipital) are dependent for their morphological differentiation and growth on the brain, whereas the bones of the skull-base, face and jaws, nasal, maxilla, etc.) are independent of the brain." De Beer, then, would see at least two systems of growth influencing the form of the skull.

Similar conflict of opinion concerning the role of the cranial base in influencing the form of the skull is evident in the divergent statements of Weidenreich and Stockard. Weidenreich ('41, pp. 378-379) states: "The deflection of the base, of course, is of some influence upon the general position of the face but it is not responsible for the degree of prognathism, as Ranke believed, and still less for the reduction of the face." On the other hand, Stockard ('41, p. 282) contends that the cartilaginous growth of the base "functions to produce the bone growth which brings about an almost continuous lengthening of the basi-cranium with the forward development and strengthening of the upper facial skeleton."

These conflicting opinions, based on comparisons of the same types of data, indicate the need for experimental evidence to sort out the

systems of growth in the skull determining the form of the brain case, the face, and the cranial architecture. The experimental method of surgical interference with normal growth has revealed the presence of intrinsic and extrinsic factors during development. Washburn ('47), for example, has demonstrated that certain elements of the skull (temporal lines, nuchal crests, and the coronoid process of the mandible in the rat) develop in direct response to, or are maintained by, muscle function and increasing muscle volume, and are independent of the expansion of the cranial cavity proper.

The vital-staining technique which demonstrates the specific sites of growth also holds an advantage in clarifying problems relating to the ontogenetic development of the skull. While the use of anthropometric techniques has delineated the major proportional changes occurring during the development of the skull, interpretation of the significance of these changes is contingent upon an understanding of the processes of bone growth, the units of growth, and the direction of growth. Thus Keith ('10), Krogman ('31), and Schultz ('40, '41) have described a backward movement of the foramen magnum during the growth of the skull in the gorilla, the chimpanzee, and the orangutan. The causes and the precise mechanisms of the backward migration of the foramen magnum have remained obscure, however, and a full understanding of them must await an analysis of the growth of the base.

Investigators using quantitative anthropometric techniques have been plagued, further, by the problem of superpositioning skull tracings for comparative purposes. That this is a recurrent problem is attested by the fact that Krogman ('51) lists 20 planes which have been suggested at one time or another as a basis for orientation, each attempting to establish an absolute basis of comparison. Adoption of a plane for comparison of different forms or serial tracings of the same form has necessarily depended on the selection of the points in the skull which are assumed to be most stable. The limitations inherent in this method are evident, for commitment to any one plane predetermines the interpretation of differences in dimension, proportion, and the direction of growth and movement in the skull. This problem, as Brodie ('41) has indicated, can be resolved only through the experimental determination of the specific sites of growth.

In the area of growth theory generally, the investigations of Thompson ('17) and Huxley ('32) are cited frequently as having demonstrated the significance of the growth phenomenon as a mechanism of evolu-

tionary change and to account for the differences in form among related groups. Although these writers based their analysis of change of form on the biological nature of the processes of growth, subsequent interest and investigation have tended to focus primarily, and almost exclusively, on the empirical formulations developed by Thompson to show systematic transformations and by Huxley to demonstrate constant differential growth ratios. Huxley's allometric formula ($Y = bx^k$) has been widely applied to describe proportional size shifts during evolution. Robb's ('35) study of the horses and Romer's ('48) study of the Pelycosaurian reptiles may be cited as examples. Simpson ('44) has stated the implications of the concept of relative growth for determining evolutionary rates of change in size of different characters in a phyletic line.

While recognition of the importance of differential growth as a mechanism of evolutionary change has stimulated the development of mathematical techniques for the treatment of dimensional data, little attention has been directed toward the rationale or logical basis for the measurements selected to describe changes in size. Rather, the focus of interest has been directed toward determining general laws of growth inferred from observed regularities in size shifts (i. e., gradients, genetic fields, etc.). The emphasis on application of mathematical techniques has resulted in descriptions of changes in size effecting shifts in form and proportion. This approach does not indicate *how* these changes take place. The utility of inferences about morphological changes derived from a direct application of the mathematical approach without prior consideration of the processes of growth and an analysis of the causal factors involved has been questioned by Waddington ('50), Young ('50), and Washburn ('53).

The solution of problems of morphological change by the technique of mathematical analysis raises the question of the nature of the dimensions selected for study and the basis of selecting these dimensions. Do the measurements submitted to the test of allometric relationship represent measures of discrete morphological elements, functional systems, or units of growth? If the measurements are considered to represent growth changes, then an understanding of growth processes is necessary as a basis of mensuration. This fact has been clearly recognized by Reeve and Huxley ('45) in their discussion of the theoretical basis of the allometric equation and the assumptions concerning the processes of growth on which it rests. Recognizing that bone growth takes place by an additive process rather than one of self-multiplication, these

authors discuss the question of whether the allometric formula can be applied to the analysis of skull growth. Basing their discussion on Brash's ('34) contention that increase in the size of the skull is due to a process of ectocranial apposition and endocranial resorption, Reeve and Huxley ('45, pp. 135-136) state that "an individual skull-bone cannot be considered as a unit of either multiplicative or additive growth," and conclude that "it seems clear that no simple concept of multiplicative or additive growth can be applied to explain changes in skull proportions." This raises a question; namely, to what units of the skull ought the allometric equation be applied in order properly to measure differential growth? The development of an experimental technique designed to demonstrate the processes of bone growth as a logical basis for subsequent mathematical analysis of differential growth and consequent change in the form of the skull would provide a solution of this problem.

In regard to the experimental investigation of the processes of skull growth, little use has been made of the vital-staining technique since John Hunter (1771) described the appositional nature of bone growth in the mandible of madder-fed pigs.

Brash's ('34) analysis of skull growth, also based on madder-fed pigs, led him to the conclusion that the growth of the cranium in size can be explained by surface accretion and surface resorption without any real separating growth at sutural lines. He considered the apparent growth taking place at the sutures as indicating reformation of the sutures required by the expanding surface and designed to maintain the relative position of the suture during increase in cranial size. Although Brash regarded the growth of the cranial base as due to a process of cartilage replacement which resulted in the growth of the bones at the ends (comparable to the growth of long bones), he did not extend his work to include a consideration of the relation of the growth of the cranial base to that of the vault or the influence of growth on cranial form.

Massler and Schour's ('51) study of cranial vault growth in the rat, using the vital-staining technique, does not support Brash's contention concerning the mode of growth in the vault. These authors demonstrate that vault growth takes place by a process of incremental growth at specific sites (sutures). By injecting animals at different ages with a dye which is deposited only in bone growing at that time, they measured the new bone deposited during intervening periods. This method revealed a greater amount and duration of growth at sutures contributing

to growth in length than at sutures resulting in growth in breadth of the vault. Massler and Schour regard the progressive elongation of the cranial vault and snout of the rat as a function of unequal growth at the individual sutures.

Moore ('43) studied the sites of cranial growth in the monkey as revealed by sectioning a single specimen which had been subjected to vital staining with the same dye, alizarin red S. His findings also indicate the suture to be the site of bone deposition responsible for increase in the size of the vault. Although Moore noted the presence of dye on all surfaces as well as in the internal structure of the bones comprising the base, he attributed this staining to a reorganization of the internal structure of the bone.

The project here reported is concerned with the processes of cranial growth as a basis for assessing the influence of differential size increase of the individual units of growth on the form of the skull. To this end, the vital-staining technique used by Massler and Schour to reveal the centers, sites, and mode of growth in the cranial vault was also extended to an analysis of the processes of growth in the face and the base of the skull.

MATERIALS AND METHODS

The subjects of this study comprise a series of 77 pure strain albino rats raised in the Physical Anthropology Laboratory of the University of Chicago. Date of birth was recorded for each litter. The animals were weaned at 25 days of age.

The method of vital staining with alizarin red S was used to determine the sites and the extent of new bone formation at different ages. (Alizarin is deposited in the new bone being calcified at the time of injection, while bone formed prior to the injection or subsequent to the period of absorption of the stain remains white.) A 2% solution of alizarin red S with a dosage of 1 cc per 100 gms of body weight was administered by intraperitoneal injection or, in very young animals, by subcutaneous injection between the scapulae. With the older animals, since the rate of bone deposition has slowed down, injection of alizarin red in full dosage on two successive days was found to be more effective in producing a deep, rich stain.

The animals were injected at varying ages in order to provide a representative series from birth to 101 days of age. The distribution of animals by sex, age injected, and age sacrificed is shown in table 1.

TABLE 1

Distribution of animals by sex, age alizarinated, and age sacrificed

ALIZARIN AGE (days)	SACRIFICED AGE (days)	NUMBER M	NUMBER F
1	4	1	1
1	5	1	–
1	7	1	–
1	9	1	–
1	10	1	–
1	15	1	–
1	20	–	1
6	10	–	1
6	13	1	–
10	15	3	–
10	16	1	–
10	20	3	–
10	25	2	–
10	28	1	–
10	30	–	1
10	35	1	–
15	17	1	–
15	25	1	–
15	30	1	–
15	35	1	–
15	40	–	1
18	25	–	1
20	25	1	1
20	28	1	–
20	30	1	–
20	35	1	1
20	45	–	1
25,26	29	1	–
25,26	32	–	1
25,26	35	1	–
26,28	50	–	1
26,28	60	1	–
26,28	65	1	–
26,28	70	1	–
26,28	80	–	1
26,28	90	–	1
26,28	100	–	1
27,29	50	1	–
27,29	55	1	–
27,29	60	–	1
27,29	65	1	–
27,29	70	–	1
27,29	75	1	–
27,29	80	–	1
27,29	85	–	1
27,29	90	–	1
27,29	97	–	1
27,29	101	–	1
31,32	35	1	–
31,32	38	–	1
31,32	41	1	–
35	36	1	–
35,36	45	1	–
40,41	45	1	–
40,41	50	1	–
40,41	55	1	–
45,46	50	–	1
45,46	55	–	1
45,46	60	1	–
50,51	55	1	–
50,51	60	–	1
50,51	65	1	–
55,56	60	1	–
55,56	65	1	–
55,56	70	1	–
70,71	76	–	1
70,71	83	–	1
70,71	97	1	–
70,71	100	1	–
	Total	50	27

Total $N = 77$

Termination of the series at 101 days of age for the oldest animal was decided upon, since it was evident from a cursory examination of the specimens that this period of time covered the major growth changes taking place in the skull of the rat.

The maceration of the specimens was greatly facilitated by soaking them briefly in a solution of one part commercial household bleach containing sodium hypochlorite to two parts of water. No specimen was left in the solution for more than 5 minutes at a time. Cleaned specimens were then rinsed in three or 4 changes of clear water and stored in a dilute solution of alcohol.

The method of analysis consisted of making qualitative observations, on the articulated skulls, of the growth centers and the sites of growth active at different ages. The mode or process of growth (i. e., surface apposition or incremental addition at the margins of the center of ossification) at the different sites of bone deposition was determined. The direction of incremental growth as revealed by the staining technique was the basis for metrical assessment. Since the sites of bone growth were known, it was possible to devise measurements at right angles to the plane of growth. The measurements reported represent diameters of whole bones. Length and height measurements were taken in the midsagittal plane, breadth measurements at the widest part of the bone.

Methodologically, the question arises: does the use of alizarin red S interfere with the normal growth of the animals, and thus make them undesirable subjects for the quantitative aspects of the study? This problem is further complicated by the age differential at time of injection and the possibility that animals react differently according to when, during the period of growth, the dye is introduced. While experimental physiological data are not available, it was observed that no animal remained ill, as the apparent result of the injection, for longer than 24 hours. Nor did younger animals appear to be more susceptible than older ones to the slightly toxic effect of the stain.

FINDINGS

Centers, Sites, and Modes of Growth Resulting in Dimensional Changes in the Skull

The Occipital Complex. The occipital bone of the rat at birth consists of 4 elements, each represented by a single center of growth: the basioccipital, the paired exoccipitals, and the supraoccipital. These

elements are arranged in two planes. The basioccipital forms the posterior floor of the brain case; the exoccipitals and the supraoccipital, the back wall of the cranial cavity.

The basioccipital increases in length and breadth by incremental growth at the margins, with the exception of the posterior margin forming the ventral border of the foramen magnum. Stained specimens show clearly a continuous increment of new bone formation extending the anterior and lateral margins of the element (fig. 1).

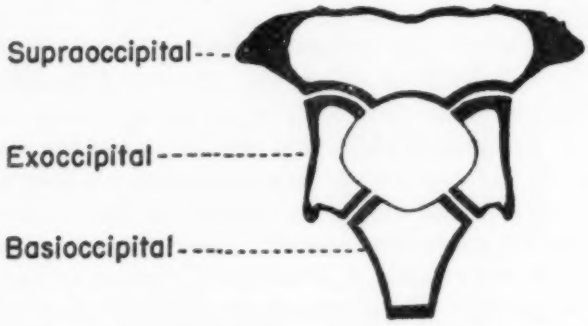

FIG. 1. SCHEMATIC DIAGRAM ILLUSTRATING RELATIONSHIP OF GROWTH SITES OF OCCIPITAL ELEMENTS TO THE FORAMEN MAGNUM IN 20-DAY-OLD RAT. (Shaded areas represent growth from 10th to 20th day; basioccipital arranged in vertical plane for diagrammatic simplicity.)

There is no indication of bone deposition suggesting incremental increase at the posterior margin of the basioccipital (and thus at basion) at any time during the 101-day period represented by this series.

Growth in length of the basioccipital takes place at the synchondrosis formed with the basisphenoid. Since the junctions of the basioccipital with the exoccipitals are set at angles to the midsagittal plane of the skull, the incremental growth at these sites contributes to increase in both length and breadth of the basioccipital.

The lateral margins of the basioccipital abutting the tympanic bullae show incremental increase without preformation in cartilage. This mechanism of increasing the lateral diameter is unlike the growth of long bones in breadth resulting from surface apposition. The surfaces (ectocranial and endocranial) of the basioccipital, after injection, are lightly stained red, indicating appositional growth resulting in an increase in thickness of the bone. The unstained band of new bone

surrounding the area of stained surface indicates clearly that the lateral dimension does not increase by surface apposition.

The distribution of the stain shows that the exoccipitals, with the exception of the medial margins comprising the lateral borders of the foramen magnum, increase in height and width by incremental growth at the margins of the growth center (fig. 1). Growth occurs at the junctions of the exoccipitals with the basioccipital and the supraoccipital as a result of endochondral bone formation, whereas the lateral margins meeting the periotic capsules show incremental growth without preformation in cartilage.

The supraoccipital also increases in dimension by incremental addition at the margins of the single center of growth. Unlike the other elements of the occipital bone, the ventral margin of the supraoccipital forming the superior border of the foramen magnum shows a " filling in " suggestive of incremental increase contributing to its vertical dimension. As compared with the nature of the staining at the other margins, however, this incremental growth is not sharply defined. While it does contribute to the vertical height of the supraoccipital in the midline, the chief effect appears to be the flattening of the superior margin of the foramen magnum during growth.

Since the elements of the occipital bone are arranged roughly in two planes, the growth sites described result in the expansion of the occiput in height, length, and breadth. While the borders of the foramen magnum undergo lipping and increase in thickness during the period studied, the pattern of staining in specimens permitted to survive for some time after injection demonstrates that incremental growth does not take place at the lateral or inferior margins of the foramen magnum. The amount of growth at the sites joining the 4 elements of the occipital determines and controls the size of the foramen magnum, as illustrated in figure 1.

The Cranial Base. The basioccipital has been discussed in connection with the growth of the occiput. The sphenoid bone in the rat forms the central part of the floor of the brain case and the lower part of the lateral walls. The basisphenoid grows in length by incremental addition at the synchondroses present at the anterior and posterior ends of the bone (fig. 2). The surface of the bone forming at the time of absorption of the stain shows a pink coloring, owing to surface apposition causing increase in thickness of the bone. Since the lateral margins of the basilar part of the sphenoid do not show a concentration of stain indi-

cating sites of incremental growth, as in the basioccipital, it is evident that increase in lateral dimension is attained by surface apposition, as in a long bone.

FIG. 2. SCHEMATIC DIAGRAM OF THE MIDSAGITTAL SECTION OF A RAT INJECTED AT ONE DAY OF AGE AND SACRIFICED AT TEN DAYS OF AGE SHOWING: (1) SITES OF GROWTH CONTRIBUTING TO THE INCREASE OF THE SKULL IN LENGTH AND HEIGHT; (2) NEW BONE (WHITE) FORMED SUBSEQUENT TO THE ABSORPTION OF ALIZARIN.

Lateral to the basilar part, the wings of the sphenoid show incremental growth at the margins forming sutures with the squamosals, the frontals, and the presphenoid, contributing to the growth of the bone in width and length. The unattached posterior margins of the wings bordering the petrotympanic fissures are sites of incremental growth also, resulting in increase in length of the pterygoid fossae and the wings of the sphenoid. The anterior ends of the pterygoid processes buttressing the maxillary tubercles show a concentration of stain and increments of new bone deposition, indicating that growth takes place by addition of bone at the anterior ends.

The presphenoid bone forms the anterior part of the floor of the brain case. The basal portion of the presphenoid grows in length by incremental addition of bone at the synchondroses formed with the

basisphenoid posteriorly and the junction with the ethmoid anteriorly (fig. 2). The wings of the presphenoid housing the optic foramina increase in size by incremental growth at the sutures.

The Lateral Aspect of the Brain Case. The squamosal bones are arranged in the vertical plane and form part of the lateral walls of the brain case. The distribution of the stain indicates that growth is effected through incremental addition at the sutural margins around a single center of growth. The free posteroventral margin bordering the postglenoid foramen is also indicated as a site of incremental growth. Since the squamosals are situated in a vertical plane, this growth increases the length and height of the brain case.

The paired frontal bones contribute to the formation of both the brain case and the face. Each bone, while developing from a single center of growth, is arranged in several planes and contributes to the dimensional increase of the skull in length, breadth, and height (fig. 2). The posterior part of the frontals meets in the midline dorsally and encircles the anterior end of the brain to join the presphenoid ventrally. Laterally and ventrally the frontals grow in length and height by incremental addition at the margins of the frontosquamosal and frontopresphenoid sutures. Ventrally, incremental growth at the sphenofrontal suture results in dimensional increase of the brain case in length and height.

At the anterolateral margins, the frontals form sutures with the maxillary bones. Incremental growth at the frontomaxillary sutures, as revealed by the pattern of staining, results in dimensional increase in both length and height of the face, since these sutures are arranged at an angle that slopes upward anteriorly in relation to the horizontal. (The growth of the dorsal aspect of the frontal bones has been described by Schour and Massler ('51) in connection with the sites of growth in the cranial vault.)

Sites of Growth in the Face. The maxillary bones form the lateral aspect of the face of the rat and house the molar dentition. The maxillae grow in length by incremental addition at the maxillopremaxillary sutures and at the maxillary tubercles at the posterior end of the tooth row. Growth at the latter site results in the lengthening of the alveolar portion of the maxilla housing the upper molars. Incremental growth at the frontomaxillary sutures contributes to increase in height of the body of the maxillary bones.

Ventrally, the maxillae form the anterior portion of the hard palate. Incremental growth at the margins of the intermaxillary suture results in a widening of the palate and separation of the parallel tooth rows formed by the upper molars.

The anterior half of the zygomatic arch is part of the maxillary bone in the rat. The stained specimens indicate clearly that the zygomatic arch grows by a process of surface apposition on the superolateral margin and bone resorption from the inferomedial aspect of the arch. This process of apposition of layers of bone on the outer aspect, with removal of old bone on the medial aspect, results in movement of the arch laterally and in increase in size of the temporal fossa. The mechanism of dimensional increase of the bizygomatic diameter results in the continuous replacement of bone tissue and in the structure of the arch itself, as compared with the mode of incremental growth which enlarges a bone by adding to it at its margins.

The zygomatic bones forming the central part of the arches also grow laterally, owing to apposition on the lateral surfaces and resorption from the medial surfaces. The same process is evident at the posterior root of the arch formed by extensions from the squamosae. The overlapping sutural junctions formed by the zygomatic bones with the anterior (maxillary) and posterior (squamosal) roots of the arch show increments of new bone formed subsequent to injection of the stain. This incremental growth results in longitudinal growth of the arches in keeping with the growth of the cranium in length.

The premaxillary bones form the anterior portion of the snout laterally and ventrally and border the nasal bones along the dorsal aspect of the snout. Each bone develops from a single center of growth. The premaxillae house the upper incisor teeth of the rat.

The premaxillae increase in size by both incremental and surface appositional modes of growth. Growth in length takes place by incremental addition at the maxillopremaxillary sutures, at the free anterior margins bordering the nasal aperture, and at the lateral edges of alveolar bone bordering the incisors. Growth in length of the premaxillae also takes place at the frontopremaxillary sutures by incremental addition. The pattern of staining also reveals incremental growth at the interpremaxillary suture on the ventral aspect of the snout, contributing to growth in the lateral dimension.

Increase in vertical dimension, however, takes place by surface apposition on the dorsal aspect of the premaxillae bordering the nasal bones

and by incremental growth at the free anterior margin of the premaxillae ventral to the nasals. No incremental growth of the premaxillae, at the nasopremaxillary junction, is evident during the 101-day period represented by this series. The mode of surface appositional growth is clearly evident in the comparison of two animals injected at the same age but sacrificed at different ages. An animal sacrificed a few days after injection shows red stain over the surface of the premaxillae bordering the nasal bones, while one sacrificed after some time exhibits a surface of white bone covering the stained surface laid down previously.

Growth of the Cranial Vault. Massler and Schour ('51) have reported on the centers, sites, and modes of growth of the paired nasals, frontals, parietals, and the interparietal that comprise the cranial vault in the rat. They demonstrated that growth of the vault takes place by incremental addition at the sutural margins around the centers of growth. This pattern of dimensional increase is confirmed by the animals of this series, as shown in figure 2.

Massler ('41) also demonstrated that the amount of growth is not always equal on the two sides of the suture. He showed that the parietals sustain a greater increment of growth than the interparietal at the parietointerparietal suture (Massler's anterior lambdoid suture). This phenomenon also has been observed in the animals of this series.

Growth of the Mandible. The pattern of staining indicates that the posterior and superior borders of the ramus comprise a continuous site of growth, largely responsible for the dimensional increase of the mandible in length and height. Stained specimens show a sharp increment of new bone extending along these margins, and including both the angle of the mandible and the anterior aspect of the tip of the coronoid process. The anterior margin of the ramus and the inferior border of the ramus do not represent sites of growth contributing to the dimensional increase of the mandible.

The addition of new bone at the tip of the coronoid process and along the superior margin of the ramus does not alter the backward angulation of the anterior border during the growth of the mandible. The fact that the stain reveals the old contours of the coronoid process in animals sacrificed as many as 30 days subsequent to injection indicates that the anterior margin of the ramus is not subject to resorption. The incremental growth at the angle of the mandible results both in backward and downward extension of the ramus as the mandible grows in length.

Growth in height of the body of the mandible is related to the specialized dentition of the rat, and since the incisors extend along the entire ventral aspect of the body of the mandible, surface appositional growth of the alveolar bone contributes to this growth in height. So also does the incremental addition of new alveolar bone, which progresses in conjunction with the eruption of the molars. The continuous eruption of the incisors is accompanied by incremental growth at the anterior margin of the body of the mandible, thereby contributing to the growth in length of the mandible. Except for the special nature and requirements of the rat's dental apparatus, the growth of the mandible in the rat is essentially comparable in pattern to the growth of the mandible of the pig reported by Brash.

The sites of growth in the midsagittal plane described as contributing to increase in height and length of the skull are illustrated in figure 2.

Sites of Bone Deposition and Resorption Resulting in Changes in the Cranial Architecture of the Rat

Analysis of animals injected and sacrificed at different ages reveals the presence of sites of bone deposition and resorption concerned primarily with changes in the architecture and proportions of the skull, rather than with dimensional increase of individual bones. These sites are therefore distinguished from those responsible for growth in size per se and are described separately.

Differential Growth of the Cortical Plates of the Vault Bones. The stained animals of this series reveal that the sutures of the cranial vault represent sites of differential growth related to changes in cranial form. The vault of the rat, rounded at birth, undergoes progressive longitudinal flattening in conjunction with growth in size. As a result, the bones of the dorsal aspect of the vault are rearranged in the horizontal plane and form almost a right angle with the supraoccipital, which is nearly vertical in orientation.

The examination of disarticulated specimens shows unequal growth of the inner and outer tables of the same bone at the sutural margin. The difference in increment of new bone formation is evident by direct comparison of the outer and inner tables of the paired bones of the vault. Beginning at 10 days of age, differential growth results in the outer table of one bone overlapping the inner table of the adjoining bone at the sutural junction. A slight incremental growth at the edges of some

of the cortical plates was noted throughout the time span covered by this series. Animals sacrificed after injection at 70 and 71 days of age showed particularly a new increment of growth at the posterior margin of the outer plate of the parietals and at the anterior margin of the inner plate of the interparietal.

The pattern of staining on the ectocranial and endocranial surfaces of the vault, examined under low-power magnification, indicates that differential surface apposition and resorption are not the mechanism responsible for the longitudinal flattening of the dorsal aspect of the cranium. The surfaces of the vault show the greatest concentration of stain near the sutural margins and less intense staining in the central areas. The same pattern of staining is found both in animals sacrificed only two days after injection and in those permitted to survive as long as 70 days after injection. The pink stain in the center area of the bone results from an increase in thickness of the bone due to surface apposition. The deeper staining near the sutural margins results from both surface apposition and incremental growth at the sutural margins.

These findings, in the rat, do not support Weinmann and Sicher's ('47) statement that the cranial vault bones flatten out during growth as a result of apposition on the endocranial surface in the central areas of the bones and resorption of the endocranial surface near the sutural margins.

Changes in the Internal Architecture of the Basioccipital Element. Examination of the surfaces and internal structure of the basioccipital element in stained specimens indicates extensive remodeling concurrent to growth in size. At approximately 15 days of age, a median ridge is formed on the ventral aspect by surface apposition. By 20 days of age there is evident resorption of bone on both sides of the median ridge posterior to the area of insertion of the longus capitis muscles near the synchondrosis. The combined processes of deposition and resorption result in the formation of troughlike depressions on either side of the median ridge, giving the lateral margins of the basioccipital a raised appearance. Anterior to the area of resorption, surface deposition results in an increased thickness of the bone near the synchondrosis. The continuing process of deposition at the anterior end of the bone, followed by resorption, results in a thinning of the body of the basioccipital which makes the bone translucent. Surface remodeling is accompanied by changes in the trabeculae, as indicated by continued staining of the internal structure at the base of the median ridge.

The changes in the structure of the basioccipital, involving both continuous deposition and resorption of bone, are related to factors of muscle tension and reduction in bone mass, and are independent of dimensional growth.

Quantitative Growth of the Skull

The sites and processes of growth described in the preceding section indicate that dimensional increase of the skull is the result of incremental addition at the borders of each center of ossification. At birth the bones in the rat skull, with the exception of the occipital complex, each comprise a single osseous unit. The individual bone, therefore, is the logical unit of study in analyzing the dimensional and proportional changes occurring during growth.

Since a mathematical analysis of growth rates determining cranial form is not the purpose of this paper, the effect of differential growth of individual bones is chiefly demonstrated graphically.

Measurements of the bones comprising the brain case and of the frontal and nasal bones in the face were taken on all specimens in the series, even though the absence of stain suggested earlier cessation of growth at specific sites. This procedure makes possible a comparison of the duration of growth as determined by qualitative and quantitative methods.

Differential Growth Rates: Curves of relative growth. To determine the phases of relative growth rates (increase in millimeters per unit time per millimeter), it is expedient to plot the measurements on semilogarithmic paper. The mean values of the measurements, grouped by 5-day intervals, are shown in figure 3.

The period of most rapid postnatal growth for all dimensions studied occurs during the first 20 days after birth, as shown by the slope of the curves. The 11 dimensions show in common an inflection between 15 and 20 days, indicating a decrease in relative rate of growth at this time. After the inflection the relative growth rates are much reduced. The greater slopes of the relative growth curves before the inflection period correspond to the accelerating phase of absolute growth completed by 20 days of age.

The relative growth rates are not constant for any considerable period of the total time during which the dimensions were studied. Although segments of each curve may be approximated by a straight line, suggesting that for short periods relative growth adheres to an exponential

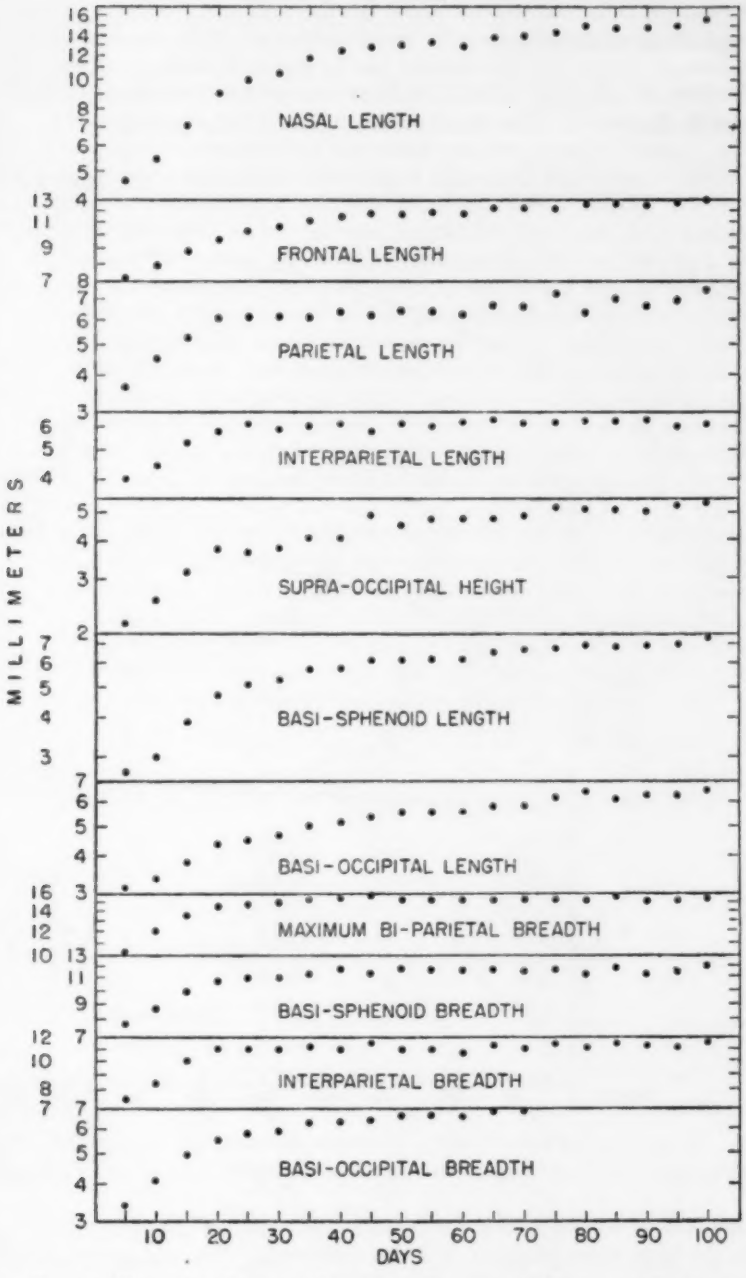

FIG. 3. RELATIVE GROWTH CURVES OF INDIVIDUAL BONES IN SKULL OF THE RAT. NOTE THE INFLECTION PERIOD AT 15–20 DAYS OCCURRING IN THE LOGARITHMIC PLOTTING OF ALL DIMENSIONS STUDIED.

formula, the complete curves show breaks indicating successive changes in rate of deceleration.

Curves of absolute growth. Absolute growth curves are shown in figures 4, 5, and 6. The decelerating phase of the curves was fitted by

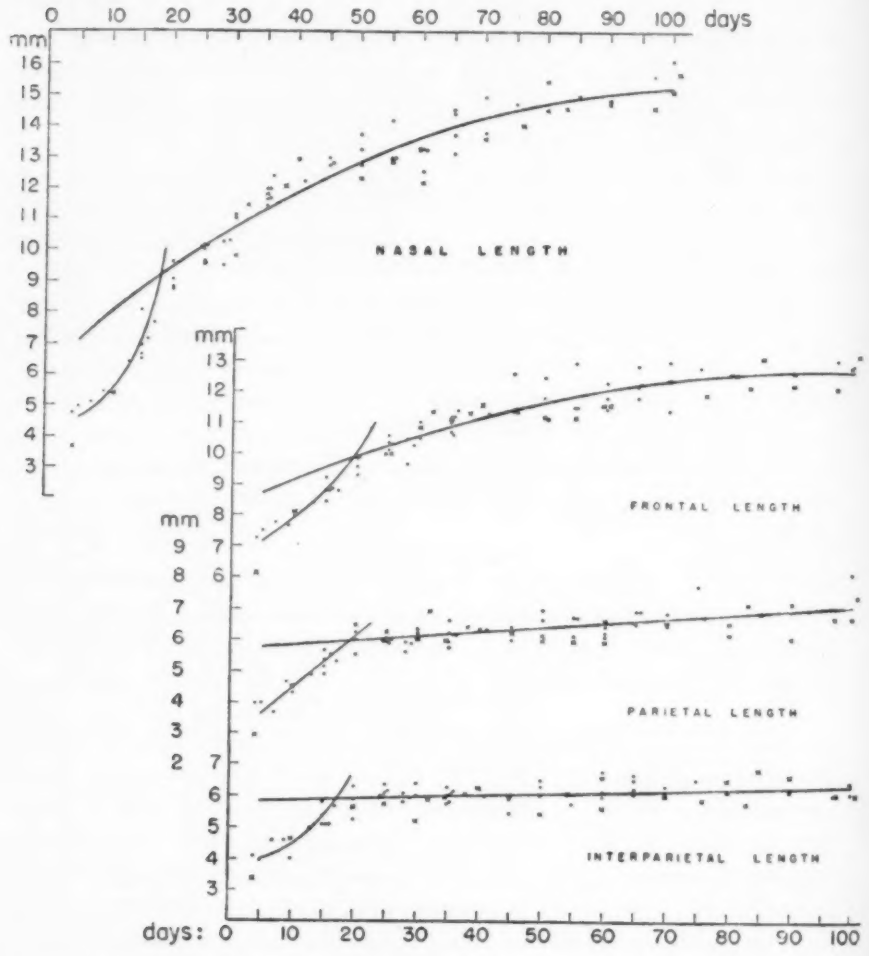
0 10 20 30 40 50 60 70 80 90 100 days
mm
NASAL LENGTH
FRONTAL LENGTH
PARIETAL LENGTH
INTERPARIETAL LENGTH
days: 0 10 20 30 40 50 60 70 80 90 100

FIG. 4. ABSOLUTE GROWTH CURVES, SHOWING GROWTH IN LENGTH OF INDIVIDUAL BONES COMPRISING DORSAL ASPECT OF SKULL OF THE RAT (dot, male; ×, female).

the method of orthogonal polynomials described by Snedecor ('46). To do so the data were grouped in 5-day intervals. The curves relate to the growth of the cranial vault and the cranial base respectively.

Dimensional change in the dorsal aspect of the skull

Growth in length of the individual bones. The staining at the sites of growth contributing to increase in length of the cranium and the dorsal aspect of the face indicates growth throughout the first 100 days of postnatal life. Continued deposition of very small increments of new bone is visible in animals injected at 70–71 days of age and sacrificed at successive periods up to 100 days.

Differences in the amount of growth and pattern of deceleration of the individual lengths is revealed in a comparison of the curves. At the 1% level of significance the interparietal and parietal lengths are best fitted by a first degree curve (a straight line), while the nasal and frontal lengths are fitted by a second degree curve (a segment of a parabolic arc). These curves (fig. 4) demonstrate the constrast in the rates of growth of the interparietal and parietal on the one hand, and the frontal and nasal lengths on the other. Specifically, the interparietal and parietal bones show rapid deceleration during the period of inflection, followed by constant, slow linear growth. The frontal and nasal bones show a much longer period of slow deceleration. Expressed in terms of size attained at 100 days of age, the interparietal reaches 85% of total length at 15–20 days, the parietals at 25 days, the frontals at 30–35 days, and the nasals at 50–55 days of age.

Comparison of the calculated attainments of the individual bones shows an incremental gradient of growth in the dorsal aspect of the skull. From the interparietal bone forward, each bone shows successively a greater total amount of growth at 100 days. (The length at 5 days of age, the increments of growth by 25-day periods, and the length at 100 days of age are listed for each bone in table 2.) The absolute size attained by each of the bones is related, not to the size at 5 days of age, but rather to the position of the bone in the skull.

TABLE 2

Incremental growth of bones in the dorsal aspect of the skull (mm)

	NASAL LENGTH	FRONTAL LENGTH	PARIETAL LENGTH	INTERPARIETAL LENGTH
Length at 5 days	4.60	7.14	3.62	3.99
Increase 5–25 days	5.49	3.11	2.44	1.93
Increase 26–50 days	2.72	1.39	.36	.13
Increase 51–75 days	1.69	.82	.35	.12
Increase 76–100 days	.65	.25	.35	.12
Total increment (5–100 days)	10.55	5.57	3.50	2.30
Length at 100 days	15.15	12.71	7.12	6.29
Increase over size at 5 days (per cent)	229.6	78.0	96.7	57.7

Growth in breadth of the interparietal and parietal bones. For this series, deposition of bone at the sites of growth contributing to increase in width of the parietals is revealed by the stain until 30 days of age. Measurement of biparietal width, however, indicates rapid deceleration until 35 days of age; after this time

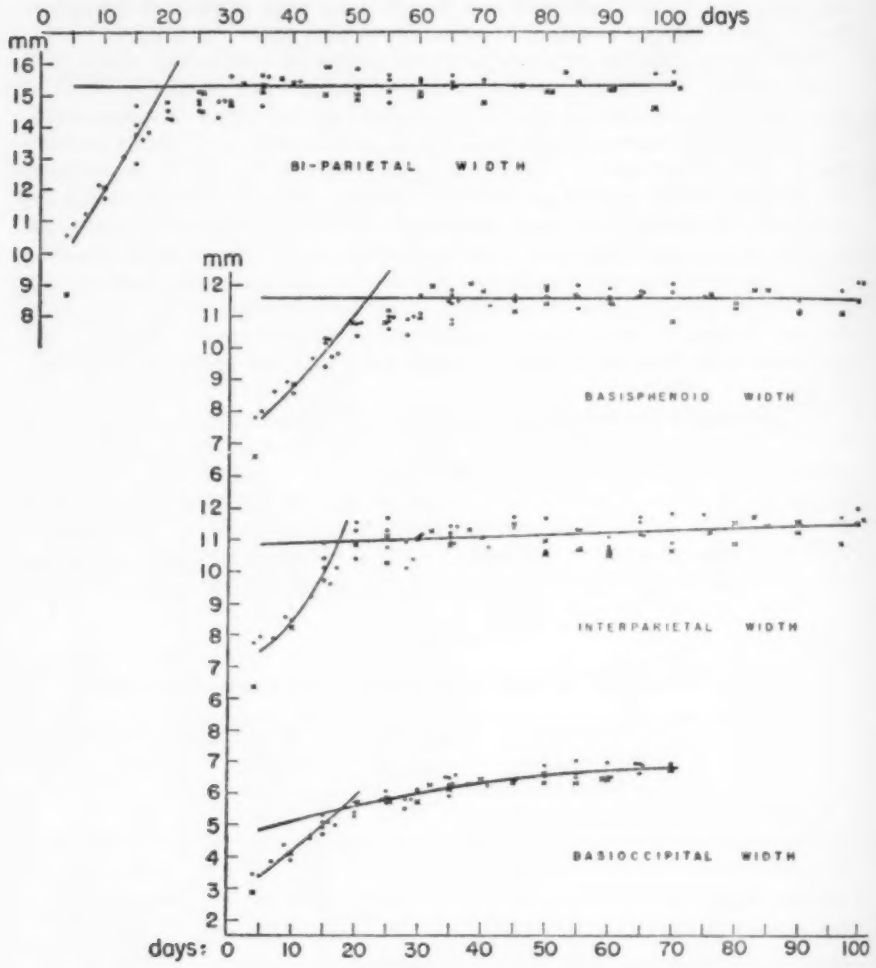

FIG. 5. ABSOLUTE GROWTH CURVES, SHOWING GROWTH IN WIDTH OF INDIVIDUAL BONES COMPRISING VAULT AND BASE OF SKULL OF THE RAT (dot, male; ×, female).

there is no significant dimensional increase (fig. 5). Of the total biparietal width 85% is achieved by 10–15 days of age. The presence of stained bone shows that interparietal breadth increases throughout the period studied. The curve of growth illustrates rapid deceleration during the inflection period and slow linear

growth through 100 days of age (fig. 5). The biparietal and interparietal widths at 100 days show an increase in size over that at 5 days of age by 48.2% and 52.9%, respectively.

Dimensional change in the cranial base. The measurements of the base here reported concern the growth of the presphenoid, basisphenoid, and basioccipital bones. The length of the presphenoid bone could not be determined for most of the series, since to do so would have necessitated disarticulating each specimen. Description of the growth of the presphenoid, therefore, is based on the values obtained from 6 sectioned skulls.

Growth in length of the individual bones. All sites of growth described as contributing to increase in base length show deposition of new bone throughout the period studied. The measurements of basioccipital and basisphenoid length comprise second degree curves, characterized by a long period of slow deceleration (fig. 6). The plotted values of presphenoid length for the 6 sectioned skulls indicate a pattern of growth similar to that of the other bones in the base.

Comparison of the total increment of growth for each of the bones of the base indicates that the greatest absolute gain in length occurs in the basisphenoid. In terms of percentage increase over size at 5 days of age, however, the greatest relative increase occurs in the presphenoid; it is successively less for the basisphenoid and the basioccipital (table 3).

TABLE 3

Growth of the bones of the cranial base (mm)

	PRESPHENOID LENGTH *	BASISPHENOID LENGTH	BASIOCCIPITAL LENGTH
Length at 5 days	2.52	2.71	3.16
Length at 100 days	6.72	7.07	6.46
Total increment	4.20	4.36	3.30
Increase over size at 5 days (per cent)	166.7	160.9	104.4

* Total values based on 97 days of age.

Growth in breadth of the basisphenoid and basioccipital bones. The presence of stained bone along the sphenoidal margins of the sphenosquamosal sutures in animals injected at varying ages is evidence of the continued growth in width of the basisphenoid throughout the period studied. The curve of growth, however, indicates no significant dimensional increase after approximately 35 days of age (fig. 5).

The basioccipital element shows deposition of new bone along the lateral margins through 100 days of age. Union of the basioccipital with the exoccipital elements begins at 50 days of age and is completed by 70 days, when the junction becomes difficult to detect. Measurement of basioccipital width was therefore

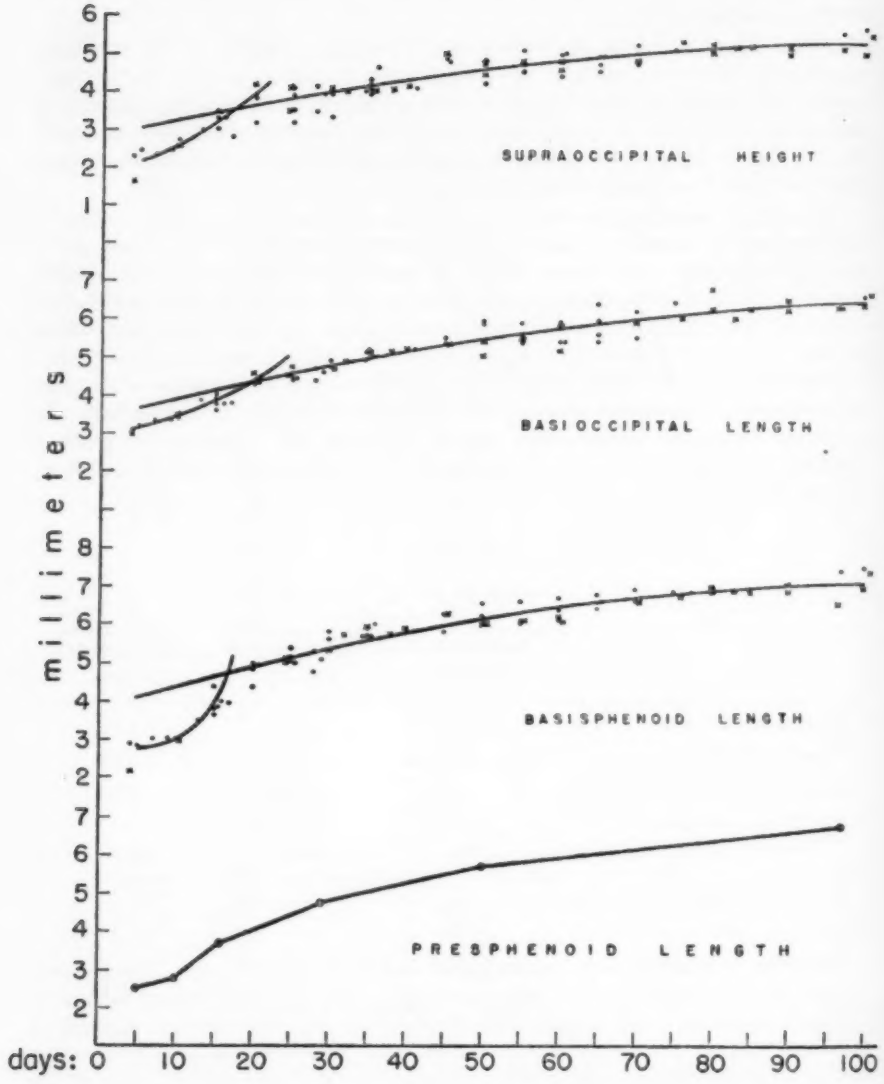

FIG. 6. ABSOLUTE GROWTH CURVES, SHOWING GROWTH IN LENGTH OF INDIVIDUAL BONES COMPRISING BASE AND OCCIPUT OF SKULL OF THE RAT (dot, male; ×, female).

attempted only through the 70th day. After the accelerating phase of growth, maximum basioccipital width is fitted by a second degree curve, characterizing slow deceleration (fig. 5).

Growth in height of the occiput. Increase in the height of the occiput occurs as the result of incremental growth at the exoccipital-supraoccipital junctions and at the supraoccipital-interparietal suture. The exoccipital elements begin to unite with the supraoccipital at approximately 45 days, and fusion is completed by 60 days of age, when the occipital complex comprises a single bone. Subsequent increase in height of the occiput results from the slow, continued deposition of bone at the superior margin of the supraoccipital through 100 days of age.

Measurements of supraoccipital height, taken in the midsaggital plane, are fitted by a second degree curve (fig. 6). The dimensional increase of supraoccipital height is similar in pattern to that described for the bones of the base; and, as with the bones of the base, approximately 85% of the total size is achieved at 50 days of age. The total size attained by the supraoccipital represents an increase of 143.8% over the size at 5 days of age (compare table 3).

Sex Differences. Mean deviations of males and females from the computed values for the total series at 5-days intervals were determined for each of the dimensions studied. For the length dimensions of the skull, the observed differences between males and females in these dimensions are not significant at the 5% level during the first 100 days of postnatal life.

In the breadth of the skull, however, test of the mean deviations indicates that differences as great as those observed might occur as a result of sampling fluctuation alone only 2% of the time for basioccipital width and only 1% of the time for biparietal and interparietal widths.

Mean deviations, "t" values, and probability (p) of chance occurrence of sex differences are listed in table 4.

Quantitative Growth of the Skull: Summary. The individual bones of the rat skull grow most rapidly during the first 20 days of postnatal life. After the accelerating phase the bones of the dorsal aspect of the skull show two dissimilar patterns of growth in length; that is, the parietals and the interparietals undergo rapid deceleration, followed by slow linear growth, while the nasals and the frontals maintain a pattern of slow deceleration resulting in greater dimensional increase. In contrast to the vault and face, the bones in the base of the skull exhibit a single pattern of decelerating growth.

Comparison of dimensional growth in length reveals that the bones of the base undergo a greater relative increase than do the bones of the dorsal aspect of the skull, with the one exception of the nasal bones.

TABLE 4

Test for sex differences of the rat skull

LENGTH DIMENSIONS	NUMBER M	NUMBER F	MEAN DEVIATION M	MEAN DEVIATION F	DIFFERENCES M AND F (mm)	t	p
Nasal	50	27	.0648	—.1463	.2111	1.587	.11
Frontal	50	27	.0398	—.1115	.1513	1.528	.13
Parietal	50	27	.0436	—.0985	.1421	1.712	.09
Interparietal	50	27	.0542	—.0863	.1405	1.925	.06
Supraoccipital	50	27	—.0064	—.0607	.0543	.835	.41
Basioccipital	50	27	—.0020	—.0204	.0184	.354	.73
Basisphenoid	50	27	.0442	—.0689	.1131	1.984	.05
BREADTH DIMENSIONS							
Biparietal	50	27	.0838	—.1641	.2479	2.666	.01
Interparietal	50	27	.0752	—.1800	.2552	2.604	.01
Basioccipital	47	17	.0387	—.1024	.1411	2.352	.02
Basisphenoid	50	27	.0330	—.0348	.0678	.779	.44

Growth in breadth of the skull at the maximum widths of the parietals and the basisphenoid shows rapid deceleration and completion at approximately 35 days of age. The growth in width of the posterior part of the skull, however, continues through the first 100 days of life. During the decelerating phase the pattern of growth in width of the dorsal aspect of the skull is slightly different from that of the base, since interparietal width decelerates more rapidly than basioccipital width. The height of the occiput shows a pattern of dimensional increase similar to that of the base, with growth continuing through 100 days of age.

These data are in agreement with the basic growth pattern described for the vault of the rat by Massler and Schour ('51). The chief differences pertain to the time of cessation of growth; the findings here reported suggest longer duration of growth at the sites responsible for increase in length of the skull and height of the occiput.

Measurement of individual bones, based on the sites of growth, indicates the presence of different patterns of dimensional increase determining proportional changes in the skull.

Proportional Changes in the Dorsal Aspect of the Skull

The dorsal aspect of the skull exhibits two major changes in proportion resulting from differential growth of the individual bones, namely: (1) reduction in the relative length of the cranial vault in comparison with the length of the face and (2) reduction in the relative width of the skull.

Changes in Craniofacial Proportions. The dorsal aspect of the cranial vault is composed of the interparietal and parietal bones and the posterior part of the frontals; the dorsal aspect of the face consists of the anterior part of the frontal bones and the nasal bones. The junction of cranium and face at the posterior margin of the frontal sinuses is marked ectocranially by a transverse depression and endocranially by a ridge of bone.

TABLE 5

Relative length of the individual bones in dorsal aspect of skull (percentage of total skull length)

DAYS	NASAL	FRONTAL	PARIETAL	INTERPARIETAL	TOTAL SKULL
5	23.77	36.90	18.71	20.62	100.00
10	24.30	35.57	20.25	19.88	100.00
15	26.76	33.21	19.98	20.05	100.00
30	32.12	31.68	18.37	17.83	100.00
50	34.70	31.54	17.37	16.39	100.00
70	36.13	31.31	16.98	15.58	100.00
100	36.71	30.80	17.25	15.24	100.00

The sequential change in craniofacial proportions is demonstrated by a comparison of the relative size of the individual bones. Table 5 shows the percentage of total skull length contributed by each of the bones at different ages. The pattern of change is shown graphically in figure 7.

The first 15 days of postnatal life are the period of greatest relative size of the cranial vault (fig. 8-B). During this time the parietal bones show a small increase in relative size, while the interparietal remains essentially unchanged. Although the cranial portion of the frontal bones grows in conjunction with the vault, the total bone undergoes a

marked decrease in relative length, owing to the comparatively slow growth at the frontonasal suture. The nasal bones show an increase of only 3% of total skull length from 5 through 15 days of age.

After 15 days of age, however, there is a shift in trend, resulting in a progressive increase in relative face length over cranial length.

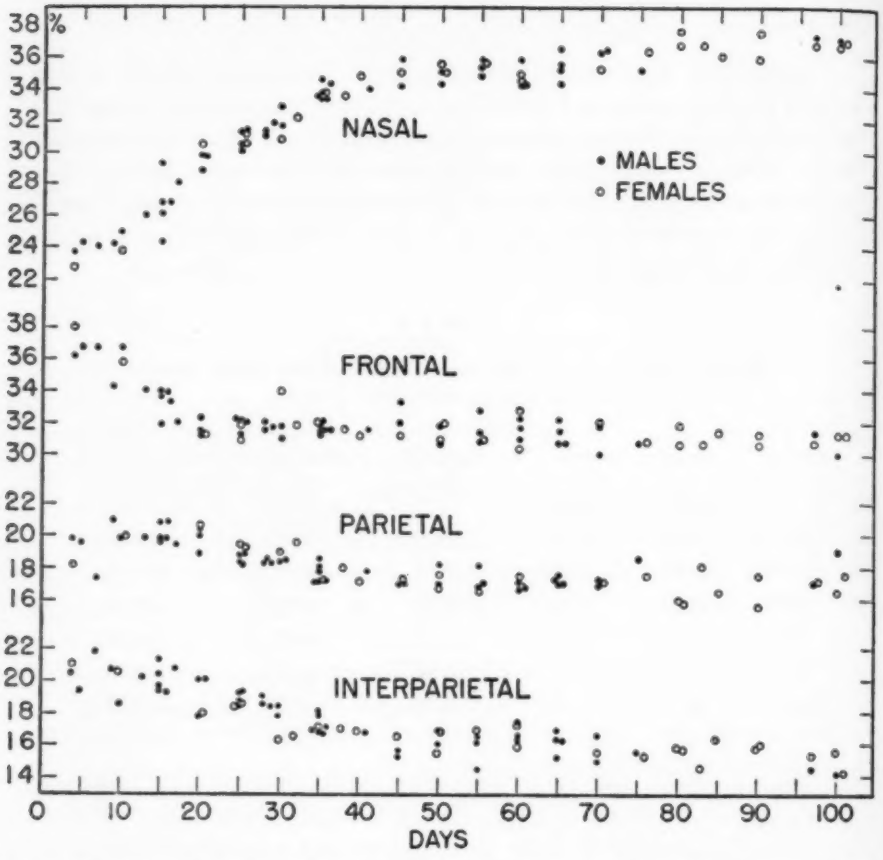

FIG. 7. PERCENTAGE OF TOTAL SKULL LENGTH OF INDIVIDUAL BONES AT DIFFERENT AGES.

The parietal and interparietal bones undergo continuous decrease in relative size through 100 days of age. The reduction in relative length of the frontals is less at successive ages, since growth at the frontonasal suture contributes greatly to the increased length of the face. The continuing relative decrease in total length of the frontals after 15 days of age is due in part to the early rapid deceleration of vault growth, and

in part to the great increase in the size of the nasal bones. The nasals are the only bones in the dorsal aspect of the skull showing increase in relative size after 15 days of age (table 5).

The postero-anterior gradient of dimensional increase in the dorsal aspect of the skull noted in the preceding section is reflected in proportional changes occurring from 15 through 100 days of age; the interparietal shows a relative decrease of 4.81%, the parietals of 2.73%, and the frontals of 2.41%; while the nasals increase 9.95% of total skull length.

Changes in the Length-Breadth Proportions of the Skull. The change in ratio of the length-breadth dimensions during the first 100 days of life contributes to the progressive dolichocephalization of the rat skull. The growth in biparietal width is completed by 35 days of age, while growth in length of the vault and face continues through 100 days of age. Continued growth of interparietal width after biparietal growth ceases results in a squaring off of the posterior end of the cranial vault. Biparietal width, which decreases 16.28% of total skull length, therefore undergoes a greater relative decrease in size than does interparietal width, which decreases only 10.97% of skull length from 5 to 100 days of age. Table 6 shows the relative size of the two breadth dimensions at different ages.

TABLE 6

Relative width of the skull
(percentage of total skull length)

DAYS	BIPARIETAL WIDTH	INTERPARIETAL WIDTH
5	53.33	38.71
10	53.88	37.92
15	51.74	37.87
30	44.59	32.90
50	41.42	30.10
70	38.80	28.55
100	37.05	27.74

As in the case of cranial length, the greatest relative size of the cranial breadth occurs during the first 15 days of life. The fact that the width dimensions show little relative decrease in size from 5–15 days is due to the rapid lateral expansion of the brain case.

Comparison of the absolute and relative sizes of the individual bones at different ages (fig. 8) reveals the proportional changes occurring in the dorsal aspect of the skull.

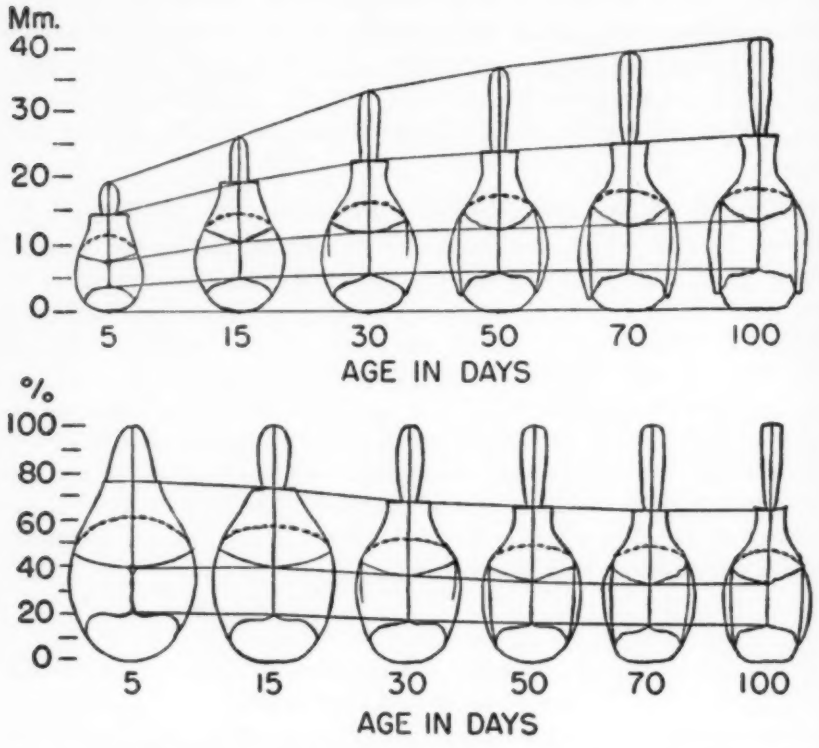

FIG. 8. ABOVE, GROWTH IN SIZE OF DORSAL ASPECT OF SKULL OF THE RAT. BELOW, PROPORTIONAL CHANGES IN DORSAL ASPECT OF SKULL OF THE RAT. ALL SKULLS DRAWN TO SAME TOTAL LENGTH TO SHOW DECREASE IN RELATIVE SIZE OF CRANIAL VAULT.

Growth of the Cranial Base and Its Relation to the Form of the Skull

We shall now consider the growth of the cranial base in conjunction with the growth of vault and face and the effect of the differential growth of these morphological units on the form of the skull.

Patterns of Dimensional Increase of Vault Length, Face Length, and Base Length. This analysis of dimensional changes is based on measurements taken in the midsagittal plane of the sectioned specimens, as follows:

Base length: total length of the basioccipital, basisphenoid, and presphenoid bones.

Vault length: total length from the posterior margin of the interparietal bone to the posterior border of the frontal sinuses.

Face length: total length from the posterior border of the frontal sinuses to the anterior margin of the nasal bones.

The dimensional increases of the base, vault, and face during the first 100 days of life result in a reversal of the size order found at 5 days of age: the vault is the longest of the three segments at 5 days and the shortest at 97 days of age, while the reverse is true of face length (table 7). Accordingly, if vault length is used as the standard of comparison, face length increases from 62.68% at 5 days to 119.83% of vault length at 97 days, while base length increases from 78.93% to 106.39% of vault length in the same period (table 7). The percentage values for base length show a slight decrease through 16 days of age, while face length maintains a consistent percentage increase throughout.

TABLE 7

A. Dimensional increase of base, vault, and face (mm)

DAYS	BASE LENGTH	VAULT LENGTH	FACE LENGTH
5	8.84	11.20	7.02
10	9.72	12.34	8.22
16	11.58	14.78	10.54
29	14.22	16.32	14.66
50	17.94	17.56	19.84
97	19.64	18.46	22.12

B. Relative size of base and face (percentage of vault length)

DAYS	BASE LENGTH/VAULT LENGTH	FACE LENGTH/VAULT LENGTH
5	78.93	62.68
10	78.77	66.61
16	78.35	71.31
29	87.13	89.83
50	102.16	112.98
97	106.39	119.83

Though the percentage ratios tend to emphasize the difference in relative magnitude of growth in these dimensions, a comparison of the incremental growth curves reveals that face length and base length follow a similar pattern of dimensional increase at variance with that indicated for the length of the vault (fig. 9). In terms of age intervals,

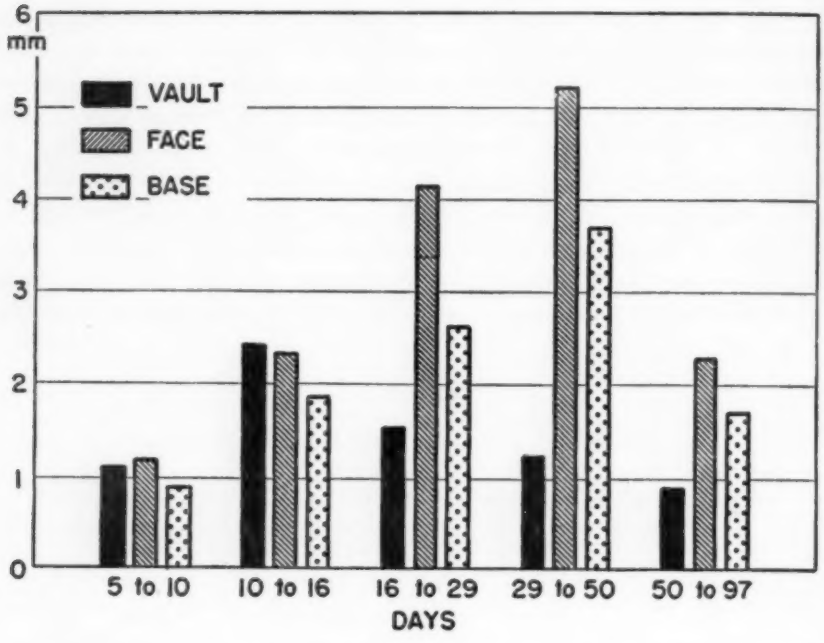

FIG. 9. INCREMENTAL GROWTH OF FACE, BASE, AND VAULT IN SKULL OF THE RAT.

both face and base show the greatest increase in length from 29 to 50 days of age, whereas the largest incremental increase of vault length occurs from 10 to 16 days of age. (This statement does not mean that the *rate* of growth of each of the segments is most rapid during the periods representing greatest dimensional increase, since the age intervals are obviously unequal.) Although face length grows more than base length at every age interval, the form of the incremental curves for these dimensions is nearly identical. The fact that the incremental increase in vault length occurring from 10 to 16 days of age is appreciably greater than that of the base during the corresponding period is responsible for the percentage decrease in base length.

Comparison of the ratios of the relative growth rates of the several dimensions further demonstrates a relationship between the patterns of growth for the face and base as contrasted with the vault. When the measurements of vault length are plotted against those of either face length or base length, on double-logarithmic paper, a curvilinear relationship is found, indicating change in the ratios of the relative rates of growth. However, when face length is plotted against base length the resulting curve approximates a straight line, showing that the ratio of the relative growth rates for these dimensions approaches a constant (fig. 10). The slope of the line indicates that face length has a greater rate of relative growth.

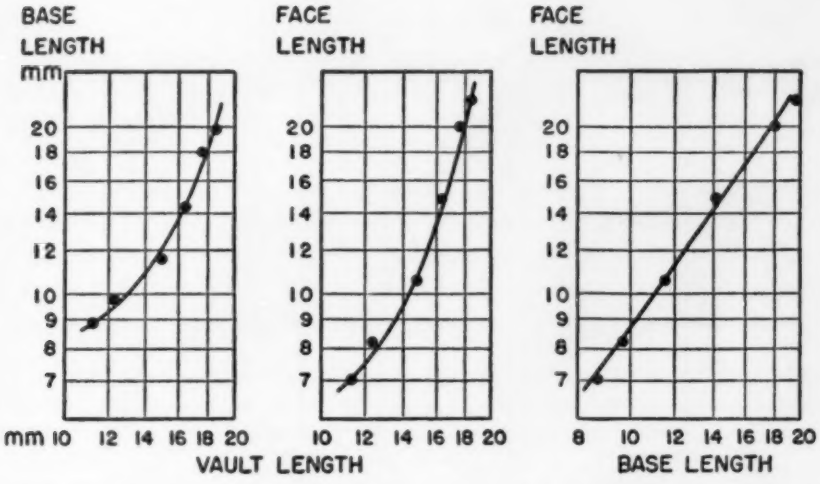

FIG. 10. DOUBLE-LOGARITHMIC PLOTTING OF VAULT LENGTH AGAINST BASE LENGTH AND FACE LENGTH, SHOWING CURVILINEAR FORM OF RATIOS OF RELATIVE GROWTH RATES CONTRASTED WITH LINEAR FORM OF RATIO OF BASE LENGTH WITH RESPECT TO FACE LENGTH.

Developmental Changes in the Proportions and Form of the Skull. The influence of differential growth on the proportions and form of the skull is here illustrated through a comparison of midsagittal sections made at different ages. Since increase in absolute dimension is not the immediate consideration, size differences have been eliminated by holding one morphological length constant in each series of diagrams in figure 11. This procedure also facilitates the analysis of the specific effect of differential growth in each of the morphological lengths. Base length is drawn to equal size in figure 11-A, while the same sections are represented with equal vault length in figure 11-B.

Since even adjoining bones show a changing spatial relationship during growth, a single bone, the basisphenoid, has been selected as

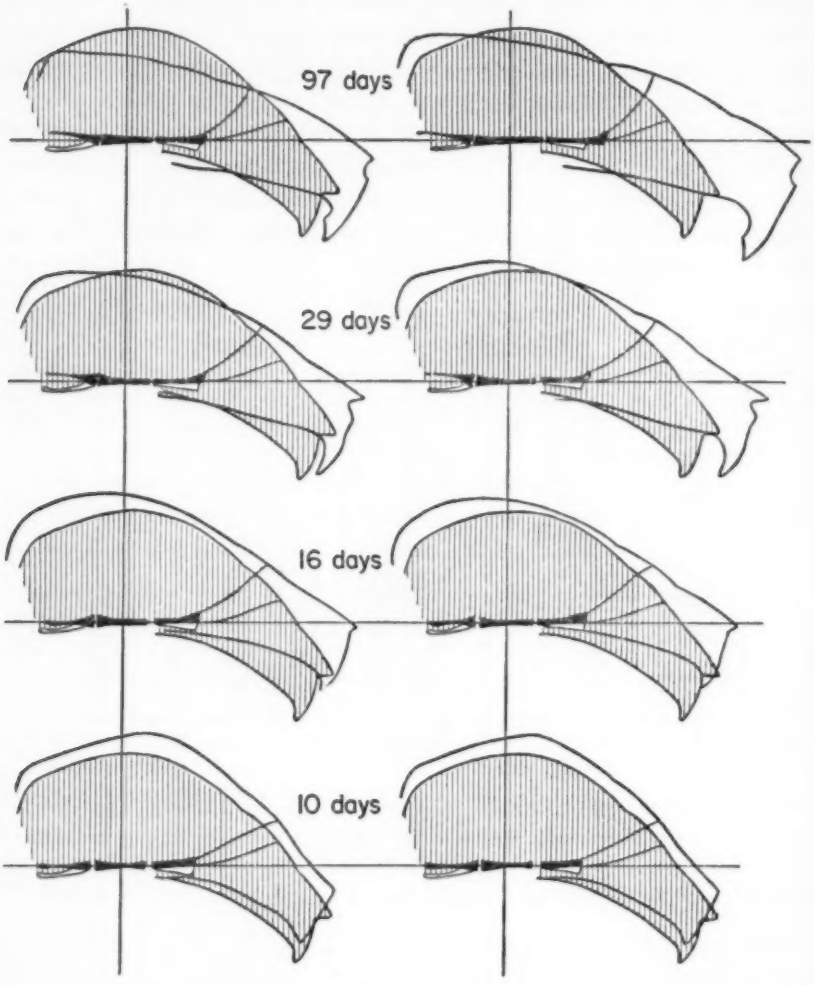

FIG. 11. MIDSAGITTAL SECTIONS OF SKULL OF THE RAT AT DIFFERENT AGES SUPERIMPOSED ON THAT OF A 5-DAY-OLD RAT: A. LEFT, BASE LENGTHS DRAWN TO SAME SIZE; B. RIGHT, VAULT LENGTHS DRAWN TO SAME SIZE. SHULLS ARE SUPERIMPOSED ON CENTER OF GROWTH IN LENGTH OF BASISPHENOIDS AND ORIENTED ON LONGITUDINAL AXIS OF THE SAME BONE.

determining the point and plane of superposition and orientation. The skulls are oriented on the long axis of the basisphenoid and superimposed on the center of growth in length of that bone.

Changes in proportion.

The cranial vault. If base length is held constant (fig. 11-A), the cranial vault exhibits a marked increase in relative *height* until approximately 15–20 days of age. During this time the relative *length* of the vault remains essentially unchanged. After 20 days of age the vault shows a progressive decrease in both relative height and relative length through 100 days of age. The decrease in relative height of the vault after approximately 15–20 days of age is also evident when vault length is held constant (fig. 11-B).

The face. If base length is held constant, the face shows a small increase in relative length from 10 to 16 days of age and very small relative increases thereafter (fig. 11-A). If vault length is held constant, however, the face undergoes considerable increase in relative length, particularly from 20 through 50 days of age (fig. 11-B).

The base. With the vault length held constant, the relative length of the base shows a slight decrease until 20 days of age and then increases continuously through 100 days of age.

Changes in the form of the skull. As a result of the differential growth of the individual bones the cranial form is modified concurrently with the observed changes in proportion. Analysis of the transformations at different ages in the rat skull indicates close dependence of form on the specific sites, timing, and direction of growth.

At 5 days of age the entire skull approximates the form of an arch; vault, base, and palate are dorsally convex, face and occiput are bent downward, and the cribiform plate of the ethmoid is deflected forward in nearly the same plane as the base.

From 5 to 10 days of age the rapid growth of the vault results in an even greater dorsal curvature in the region of the frontoparietal suture. Concurrently the slowly growing base unbends so that the three bones of which it is composed become aligned in the same plane. The rapid increase in height of the skull is accompanied by an upward, vertical shift of the cranial vault and face, relative to the base, with little change in the angulation of face, palate, or occiput.

From 10 to 16 days of age the greatest convexity of the vault is shifted posteriorly to the region of the parieto-interparietal suture. Owing to incremental growth at the maxillary tubercles, the alveolar arches become elongated and move forward from the cranial base, thereby providing space for the erupting molars. While the palate is moved forward in conjunction with the growth of the alveolar arches and aligned more closely in the plane of the base, growth at the maxillo-premaxillary sutures raises the anterior end of the face and decreases the dorsal curvature of the palate. Growth of the presphenoid anteriorly contributes to the forward movement of the cribiform plate of the ethmoid at the ventral margin. As a result of these changes the face is rotated forward and upward into a position anterior to the brain case.

After the major expansion of the cranial vault during the first 20 days of life, the more sustained growth of the bones comprising the base and the face results in a progressive modification of the skull toward a low, flat-vaulted dolichocephalic form.

In the base continued growth at the spheno-occipital synchondrosis results in the unbending of the occiput, elevation of the interparietal, and consequent reduction in curvature of the vault. The important factor in this modification is the greater increase in length of the posterior part of the base (basioccipital) as compared to the posterior portion of the vault (interparietal). The backward movement of the basioccipital swings the exoccipitals and the supraoccipital out from the base. Since the interparietal must be maintained in articulation with the supraoccipital, the interparietal is elevated at the posterior margin until it forms nearly a right angle with the posterior wall of the vault. The fact that the basioccipital element is also elevated with the occiput is evident in a comparison of midsaggital sections (fig. 11). These changes transform the base from a dorsally convex structure at 5 days of age to one slightly convex ventrally at 100 days of age.

The changing base-face relationship described earlier is continued through 100 days of age. The anterior end of the base is projected forward faster than the vault, owing to the greater addition of bone at both ends of the presphenoid than at the frontoparietal suture. The rotation of the ventral margin of the cribiform plate of the ethmoid toward an increasingly vertical position takes place in conjunction with the elongation of the base.

Since the frontomaxillary suture is curved backward and downward, growth at the upper, more vertical, part projects the face forward, while growth at the lower, more horizontal part moves the alveolar arches downward and forward. Growth at the sphenoid buttresses of the maxillary tubercles after the eruption of the molars deflects the posterior part of the dental arch ventrally. The combined effect, therefore, is one of continued rotation and elevation of the face into a plane more closely approximating that of the vault.

DISCUSSION

The data reported in preceding sections are here discussed in terms of their relevance for: (1) the nature of the growth processes and their methodological implications for the analysis of cranial form and (2) the significance of growth patterns for the interpretation of the factors influencing the form of the mammalian skull.

Processes of Growth in the Skull. To assess the changing form and proportions of the skull during ontogenetic development, attention must be directed toward determining the units of growth and the sites of bone deposition, rather than toward the histological nature of bone growth per se. In this connection, the proper selection of measurements depends on whether the skull grows essentially as a single unit, owing

to surface apposition and resorption, as claimed by Brash ('34), or whether increase in the size of the skull is the result of separating growth by incremental addition at the margins of the individual bones, as concluded by Massler and Schour ('51).

The findings here reported, derived from application of the vital-staining technique, indicate that both processes are operative in effecting an increase in the size of the rat skull, although they are of greatly unequal significance. Thus the individual bones (or the individual elements of a bone complex such as the occipital) comprise the units of incremental growth in the cranial vault, the cranial base, and the face, while the growth of the zygomatic arch, as a unit, results from the continuous surface apposition on the lateral aspect and surface resorption from the medial aspect. The arch of the rat is thus continuously reconstituted of new bony material during the course of lateral growth, in a manner very similar to the pattern of growth described by Brash for the zygomatic arch of the pig. Even in the rat, however, growth in length of the zygomatic arch takes place by incremental addition at the sutures.

The fact that independent investigations using the vital-staining technique can result in conflicting interpretations of the nature of growth processes in the skull requires explanation, however, if the derived data are asumed to have universal application for the interpretation of the mammalian skull. As far as the basic mechanisms of growth are concerned it matters little that different mammalian species were studied, but it is important to note that the youngest animal illustrated in Brash's paper is over 24 weeks of age, while the earliest age when madder-feeding ceased was 20 weeks. Brash does not indicate the ages at which madder-feeding was begun. Thus it is possible that the intersutural growth in the brain case of the pig (in conjunction with the rapid pattern of expansion of the brain) was completed before madder-feeding was begun. The early completion of intersutural growth observed in the cranium of the rat points to the necessity of beginning staining of specimens soon after birth and, further, of studying comparable phases of growth in different species.

While the role of the individual bone as a unit of accretionary growth in brain case and face is clearly evident, it must be recognized that variation in the number of sites of incremental bone deposition and in the amount of surface apposition will occur according to the particular architectural relationships existing in the skulls of different

species. For example, in the rat the incisors extend along the entire ventral aspect of the body of the mandible; therefore surface appositional growth of the alveolar bone at this site contributes considerably to the height of the mandibular body.

In the pig, however, the less specialized dentition is confined to the superior aspect of the body of the mandible, and Brash ('34) reports that the ventral aspect of the body does not comprise a site of bone growth contributing to an increase in the height of this structure. Aside from these differences, which are directly related to the specialized nature of the rat dentition, the mandible in both animals shows essentially the same sites and modes of growth. The relative massiveness of the skull in the species selected for study must also be considered. Thus the thin-boned cranium of the rat will demonstrate little surface apposition, while the heavy, thick bones of the pig cranium are the result of extensive surface apposition.

By measuring the total increment of bone deposited at each suture, Massler and Schour ('51) clearly demonstrated that proportional changes in the vault are due to unequal growth at the different sutures. The data here reported, however, indicate that the size of the increment contributed by each of the adjoining bones at a common suture is not always the same. In the case of the parieto-interparietal suture, particularly, the increment at the posterior margin of the parietal bones is roughly twice as large as that at the anterior margin of the interparietal bone.

The interpretation of Massler and Schour ('51) is that the intersutural trabecular growth is a response to tension caused by the intracranial pressure exerted by the expanding brain. However, the fact that differential growth takes place at a common tension line (suture) suggests that intracranial pressure is not the only factor controlling the growth of the bones in the cranial vault. It is possible that the centers of ossification have an individual specificity in terms of growth potential. This point has implications for the measurement of differential growth in the skull, since a single measurement of the total increment at a given suture may confound two different rates of bone deposition.

Thus far interpretation of the processes of growth revealed by the vital-staining technique has centered on the mechanisms by which increased size and proportional changes in the skull take place. A related problem concerns the mechanisms responsible for the changes in cranial *form* occurring concurrent to changes in proportion. Several

authors, as cited by Murray ('36), advance the hypothesis that as the radius of the cranium is increased the curvature of the individual bones must be reduced. Weinmann and Sicher ('47) and Brash ('34) contend that the flattening of the arc of each bone is accomplished by a process of differential apposition and resorption on the outer and inner surfaces of the vault, while Mair ('26) is of the opinion that only differential apposition occurs on both surfaces.

Neither of these interpretations is corroborated by the pattern of bone deposition observed during the extensive longitudinal flattening of the rat vault. No evidence was found of resorption from the surfaces of the vault or differential apposition sufficient to account for the radical changes in relationship of the vault bones during the first 100 days of life. To postulate that the mechanism responsible for the extreme flattening of the rat vault comprises a surface phenomenon, one must assume complete reconstitution of the component bones by successive replacement of the bony material.

An alternative hypothesis is offered here: that the changes in form of the rat skull are the result of spatial reorientation of the individual bones, and that the differential growth of the inner and outer cortical plates observed at the sutural margins represents the mechanism of adjusting the changing relationship of adjoining bones. The relative significance of unequal growth of the cortical plates in modifying cranial form could be tested by microscopic measurement of sections through the sutures of stained specimens of different species.

The evidence indicating the sites of cranial growth, as revealed through experimental investigation, greatly simplifies the problem posed by Reeve and Huxley ('46) concerning the unit of growth regarded as a basis for exploring allometric relationships or differential growth in general. For the analysis of relative growth as a mechanism of evolutionary change (Simpson, '44), particularly in the case of paleontological materials, where determination of growth increments is impossible, the diameters of individual bones in the skulls of related groups may be measured. In the case of laboratory animals, however, determination of the increment of growth at specific sites and at particular time periods, made possible by the vital-staining technique, permits the study of differential growth rates within a single bone. Further, this approach opens an avenue for the study of the related problem of the existence of gradients of growth in such structures as the cranium and the face, as suggested by the work of Thompson ('17) and discussed by Huxley ('32) and Child ('41).

In selecting points or planes for superpositioning serial tracings of skulls, prior analysis by the vital-staining technique indicates the sites of active bone deposition responsible for directional growth in the skull. Selection of points for superpositioning therefore need not be based on conventional landmarks assumed to maintain a stable position in the skull. Rather, the investigator can take account of the directions of growth and changing spatial relationships of the bones in the particular species under consideration. In this connection it is important to recognize that an anatomic landmark that shows no evidence of bone deposition cannot for that reason be assumed to be a fixed point in the skull.

For example, the point basion in the rat is shifted posteriorly, owing to addition of bone at the spheno-occipital synchondrosis, while there is no evidence of addition of bone at this point proper. In the rat, moreover, the conformation of the cranial vault undergoes considerable modification after growth in this region is essentially completed, owing to accommodation of the bones in the vault to continued growth of the base.

These facts illustrate the complexity of selecting points in the skull as a basis for establishing a plane assumed to have interspecific validity. Since the complex changing spatial relationships of the bones in the skull are a function of different rates of growth at all sites contributing to incremental growth, selection of a basis for superpositioning ultimately leads to the conclusion that successive growth changes can be viewed only in reference to a single bone in the skull. As Krogman ('51, p. 414) remarks, " there are, as far as we know, no two points in head and/or face which, during growth, stand in unvarying relation to one another."

Patterns of Growth and Change in Form of the Skull. The growth pattern of the rat skull is the result of two basic systems of growth: (1) early rapid expansion of the brain case in conjunction with the growth of the brain and (2) slower growth of longer duration, resulting in elongation of the cranial base and forward projection of the face. These systems are evidenced by the growth curves of the individual bones comprising the vault and the base-face complex and by the duration of active bone deposition at specific growth sites, as revealed by alizarin staining.

The changing form described for the rat skull is a function of the sequential influence of these primary systems of growth. During the first 20 days of life rapid growth of the brain is the major factor

determining cranial form. After the early expansion of the brain case, however, the more persistent growth of base and face result in an unbending of the skull from the cranial base, correlated flattening and reduction in the relative height of the vault, posterior movement of the foramen magnum, and elevation of the occiput posteriorly and the face anteriorly. These changes in form are directly attributable to the altered spatial relationships between the bones in the vault and those in the base-face complex. This altered relationship is brought about by the disproportionately greater growth of the base-face complex subsequent to enlargement of the brain.

Reference to the literature on the development of the anthropoid skull and the human skull shows that the systems of growth and their influence on the form of the skull, as described here, are not only characteristic of the rat but also represent deep-seated factors affecting the form of the mammalian skull. Thus Schultz ('40, '41), in detailing ontogenetic changes in the skulls of the chimpanzee and the orangutan, emphasizes: the extremely rapid growth of the brain during the infantile period (to 85 and 90% of adult size for chimpanzee and orangutan, respectively); the subsequent enormous expansion of the face in conjunction with eruption of the permanent dentition and therewith the backward shift in position of the occipital condyles and the foramen magnum; and migration of the orbits from beneath the brain to a position almost in front of it.

The changes in cranial form resulting from the early completion of cranial growth and the more sustained expansion of the face are clearly revealed in Schultz's illustrations (fig. 12). Since Schultz conveniently reduced the skulls at all ages to the same length, the striking backward migration of basion clearly demonstrates the disproportionately greater increase in length of the cranial base over the length of the cranial vault. Of particular significance for the present discussion is the fact that, with the greater elongation of the base, the occipital squama is reoriented nearly into the vertical plane, while the orbits are elevated to a position in front of the brain. These changes are instrumental in producing the progressive flattening of the cranial vault and the radical modification in cranial form in the chimpanzee and the orangutan after the growth of the brain in these animals is essentially completed.

Similarly, the development of the gorilla skull shows the effect of basilar growth on cranial form. Krogman ('31, p. 106), in discussing the changing dimensions of the posterior aspect of the skull, comments:

"The increase noted is the measure of the backward and upward swing of the foramen magnum. . . . Here the period just preceding and succeeding the eruption of the first molar is the time of greatest movement, and again just before the eruption of the third molar, at a time when the superior portion of the occiput of the male skull is being sharply pulled forward and up, shifting the inferior portion backward and up."

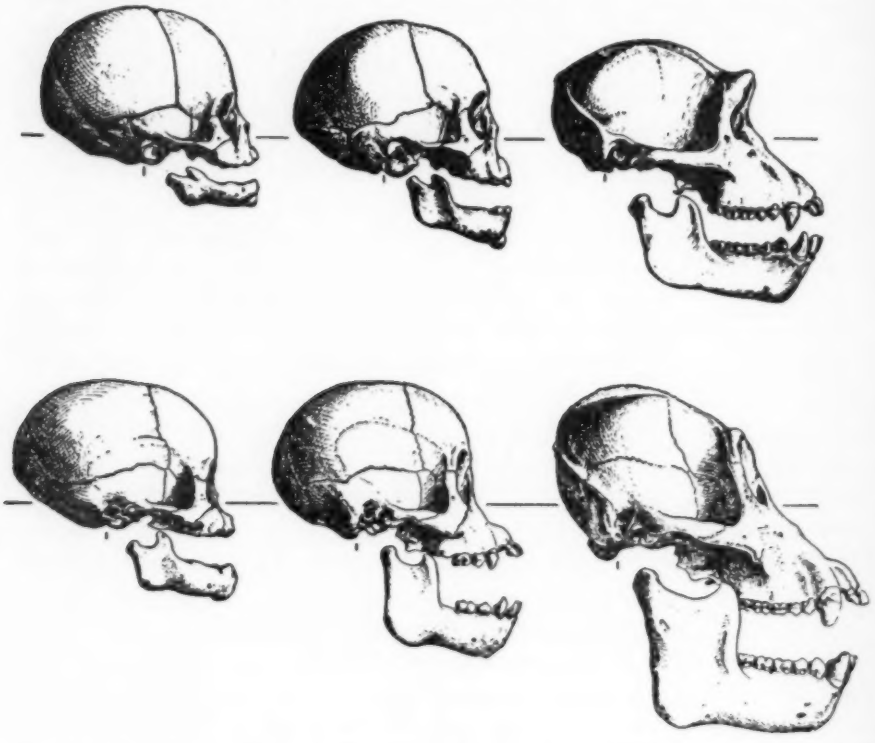

FIG. 12. TOP, LATERAL VIEW OF FEMALE FETAL, INFANTILE, AND ADULT CHIMPANZEE SKULLS DRAWN TO SAME SKULL LENGTH. (AFTER SCHULTZ, '40.) BOTTOM, LATERAL VIEW OF MALE NEWBORN, INFANTILE, AND ADULT ORANGUTAN SKULLS DRAWN TO SAME SKULL LENGTH. (AFTER SCHULTZ, '41.) IN EACH CASE BASION IS INDICATED BY VERTICAL LINE.

These modifications take place, it should be noted, after the period of rapid cranial growth, during which the brain was the chief determinant of cranial form.

The form of the human skull, in contrast to that of the anthropoid, appears to undergo relatively little change during ontogenetic develop-

ment. On the basis of a serial roentgenological study of the same individuals from three months to 8 years of age, Brodie ('41, p. 251) concluded that "the morphogenetic pattern of the head is established by the third month of postnatal life, or perhaps earlier, and that once attained it does not change."

Brodie's conclusions reinforce the findings of such comparative anatomists as Welcker, Bolk, Schultz, Weidenreich, Krogman, and others concerning the relative stability, in the modern human skull, of the position of such structures as the foramen magnum, the orbits, and the cranial base, and of the general configuration of the cranium. Thus it is evident that a much closer correspondence exists in the growth rates of the component structures of the skull in man than is to be found in those of anthropoids.

However, certain facts suggest that modern man reflects the same pattern of early cranial expansion and subsequent more sustained growth of the cranial base as that found in the anthropoids, although in lesser degree. Thus Scammon ('30) indicates that by 8 years of age (the age at which Brodie's study was terminated) the brain has completed 95% of its total growth, and the data of Simmons ('44) show that approximately 94% of adult head length and breadth have been attained at this age. Count's ('42) analysis of Brodie's data on the cranial base indicates that at 8 years of age the length of the base from sella turcica posteriorly has a higher rate of growth than the anterior cranial floor from sella turcica to nasion; and further, that the rate of growth of the anterior length decelerates more rapidly.

Probably related to the more sustained growth of the posterior part of the base is the fact that the cartilaginous plate at the spheno-occipital synchondrosis is not completely replaced by bone until approximately the 18th year of life (Weinmann and Sicher, '47).

These facts are highly suggestive of the influence of differential growth in cranial vault and cranial base in bringing about the slight elongation of the head observed during growth. They warrant further study of ontogenetic changes in form after cessation of brain growth.

The interpretation here advanced is in conflict with Weidenreich's ('41) theory, namely, that the brain is the sole determinant of form in the mammalian skull and that the enlargement of the brain has a depressing influence on the growth of the face. However, a consideration of the changes in form, both ontogenetic and phylogenetic, detailed by Weidenreich for various mammalian groups shows no essential incompatibility with our interpretation.

Further, the data on microcephalic subjects discussed by Weidenreich himself furnish evidence of the importance of the growth of base and face in determining cranial form. Weidenreich illustrates the skull and endocast of a Basuto microcephal (his figures 40 and 43) and describes the "anthropoid characteristics" of the skull. He remarks (p. 396) that "the form and proportions of the brain . . . fail to show any appreciable differences when compared with the normal human brain." The form of this skull and microcephalic skulls in general he attributes to the fact that the brain grew to only a small size. Such an explanation accounts only for the absolutely small size of the vault. The ultimate form of the microcephalic skull is due rather to continued growth of face and base to nearly normal size after the arrest of brain growth. The accommodation of arrested vault growth to the continued growth of the base is reflected in Weidenreich's ('41, pp. 393, 394) comment concerning one of the skulls he describes, that "it is of great interest that there is no indication of a deflection of the cranial base as is characteristic of man but that its axis forms a perfectly straight line as in gorilla." (See his figures 29 and 42.)

The more extreme condition in which the brain is absent (anencephaly) further illustrates the independence of the base-face complex during development. De Beer ('37, p. 485) states: "In such skulls there is no cranial vault at all, and the bones which would normally form it are present but extremely small and abnormal. On the other hand, the bones of the skull-base (basioccipital, basisphenoid, periotic, etc.) are fairly normal, as are those of the face."

Conversely, the data drawn from other types of pathological conditions, such as achondroplasia, in which the growth of the base is arrested, present a situation where the expansion of the brain constitutes the sole determinant of the form of the skull. In such instances the failure of the base-face complex to elongate leaves the skull in a globular form, with a highly arched base and a depressed nasal region. It is significant that in describing the alterations required to correct the deficiencies in the form of the achondroplastic skull, Stockard ('41) details a series of changes in exact reverse to those postulated by Weidenreich as having occurred in human phylogeny.

Turning more directly to the problem of interpreting the evolutionary changes in human cranial form, it would appear that the progressive brachycephalization of the hominid skull cannot be regarded simply as a function of an allometric growth relationship, in which

the brain is the independent variable and the face the dependent variable. Such an interpretation reduces the form of the skull to a single system of growth in which the face has no adaptive significance.

The data presented here suggest, rather, that the form of the skull is primarily the result of the interaction of two functional systems of growth. If an allometric relationship is present in the skull it would appear to relate the base to the face, rather than the brain case to the face. In terms of the causal determinants of cranial form, the brachycephalization of the human skull would appear to be the product of an adaptive trend in which the size of the brain and the size of the face have differential selective value.

SUMMARY

The purpose of this study was to determine the processes and systems of growth influencing the form of the mammalian skull. The experimental technique of staining the growing bone in the rat with alizarin red S was used in order: (1) to reveal the specific sites and modes of growth resulting in an increase in the size of the skull and (2) to assess the effects of differential growth at these sites in modifying cranial form.

The following findings are reported:

1. Increase in the size of the skull takes place as the result of two growth processes. The enlargement of the brain case and the face is due to separating growth at the sutures and at the synchondroses by incremental addition at the margins of each center of ossification. The zygomatic arch grows as a single unit by continuous surface apposition on the lateral aspect and surface resorption from the medial aspect. The individual bone, therefore, comprises the unit of growth in the brain case and the face.

2. Proportional changes in the brain case and the face are effected by differential growth at the sutures and at the synchondroses joining the individual bones. Differential growth thus results in changes in the diameters within the individual bones and also in unequal size increase between the component bones of the brain case and the face.

3. Modifications in the cranial form of the rat are caused by spatial reorientation and changing accommodation among individual bones necessitated by disproportionate growth. Differential growth of the inner and outer cortical plates at the sutural margins is the mechanism of adjusting the changing relationship of adjacent bones. No evidence

was observed of resorption from the surface of the cranial vault or differential apposition sufficient to account for the radical changes in relationship of the vault bones during the first 100 days of life.

4. The growth pattern of the rat skull is the result of two basic systems of growth: (a) early rapid expansion of the brain case in conjunction with the growth of the brain and (b) slow growth of longer duration, resulting in elongation of the cranial base and the face. These systems are evidenced by the growth curves of the individual bones comprising the cranial vault and the base-face complex and by the duration of active bone deposition at specific growth sites, as revealed by alizarin staining. The changing form described for the rat skull is a function of the sequential influence of these primary systems of growth.

5. Reference to the literature on the ontogenetic development of anthropoid and human skulls shows that the systems of growth described for the rat represent deep-seated factors affecting cranial form. Examination of ontogenetic changes in the form of the skull of the chimpanzee, the orangutan, and the gorilla reveals a pattern of early, rapid cranial expansion, followed by more sustained growth of the cranial base and the face. The interaction of these two systems of growth results in flattening and progressive elongation of the cranium of the anthropoid, accompanied by backward migration of the foramen magnum and elevation of the occiput. Related data on human microcephalic, anancephalic, and achondroplastic subjects further substantiate the existence of two basic systems of growth and the influence of growth failure on the part of either system on cranial form.

ACKNOWLEDGMENTS

The writer is indebted to many persons for help and support with this project. Particularly I wish to express my gratitude to the Wenner-Gren Foundation for Anthropological Research, which aided me with a grant for carrying out the study; to Dr. S. L. Washburn, Department of Anthropology, University of Chicago, for his advice and counsel during the entire course of this investigation; to Dr. Maury Massler, Department of Graduate Pedodontics, School of Dentistry, University of Illinois, for making available a series of alizarinated rats during the preliminary phase of the investigation; to Dr. E. C. Olson, Department of Geology, University of Chicago, for technical assistance; to Dr. Gabriel W. Lasker,

Department of Anatomy, Wayne University College of Medicine, for critical reading of the manuscript; and to Dorothy L. Tyler, Editor of Publications, Merrill-Palmer School, for editing the manuscript for publication.

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ON THE RELATIONSHIP BETWEEN MENARCHEAL AGE AND ADULT BODY STRUCTURE

BY LENNART JACOBSON

Department of Anatomy and Department of Obstetrics and Gynecology, University of Lund, Sweden

INTRODUCTION

WITH the advent of puberty the infantile body-build begins to change in a masculine or feminine direction. The nature of the resulting sex differences in adult body-build has been investigated somatometrically by Wolff and Steggerda ('43), Bayley and Bayer ('46), Reynolds ('49), Tanner ('51), Edwards ('51), Garn and Saalberg ('53), Lindegård ('53) and others. The adult female body-build differs from the male especially in the following respects. In females the long-bone lengths, the degree of skeletal sturdiness and the total amount of muscle tissue are smaller than in males, while the thickness of the subcutaneous fat layer is larger. In addition the sexes differ with respect to the proportions between certain body dimensions. In females the upper extremities are shorter in proportion to the lower. Further, females have a larger bi-iliac breadth in proportion to the bi-acromial breadth as well as to the lengths of the long bones.

The purpose of the present study was to ascertain to what extent any relationship exists between the age of menstrual onset and the adult female body structure.

MATERIAL

The investigation was based on a material consisting of somatometric and functional data concerning 300 adult Norwegian hospital nurses. The material was collected and published by Schiøtz ('36). The same series was employed by Lindegård ('53) for an analysis of sex differences in body-build.

The ages of these women ranged from 20 to 34 years, the mean being 23.6 years. Sixty-nine per cent belonged to the age group 20–24 years; only 1.2% were more than 30 years old.

Data about the age at which menstruation initially occurred were available in 288 cases. Concerning the remaining 12 cases figures were

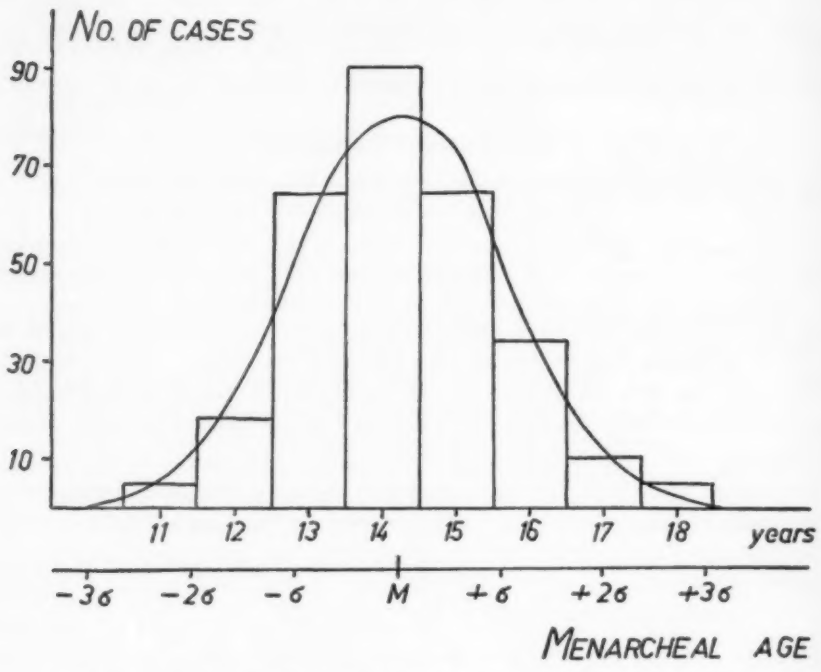

Fig. 1. Comparison Between the Frequency Distribution of the Menarcheal Age and the Normal Distribution Curve.

lacking or uncertain. The menarcheal ages ranged from 11 to 18 years, the mean being 14.2 ± 0.1 years with a standard deviation of 1.4 years. The frequency distribution of the menarcheal age agrees visually well with the normal frequency distribution (figure 1).

METHODS

Body structure was analysed according to a method devised by Lindegård ('53). This method somatometrically rates the position of an individual on scales for certain continuous variables. The system comprises 4 variables, called *length, sturdiness, muscle* and *fat factors,*

referring to the amount and distribution of bone, muscle and fat tissues. A new method, devised by Lindegård ('53) for partial correlation and regression, was used to calculate the individual values of these and other measures of body structure. The calculations are illustrated by the following example.

In the present series the regression of the hand length on the radius length is satisfied by the linear function $Y = 0.34X + 8.9$, in which X denotes the radius length. From this regression the difference between the hand length and corresponding regression mean is determined. In this way the *residual* hand length after elimination of its interdependence with the radius length, *i. e.* F hand length (radius length), is obtained for each case. The residual expresses the divergence of hand length in an individual from the average hand length of persons with the same radius length. By determining the residuals for every case in the series a *residual distribution* is obtained. The residuals can be subjected to new correlation or regression analysis with regard to either absolute dimensions or other residuals (*cf.* fat factor below).

The following measurements or residuals represent the different factors:

length factor: radius and tibia lengths,

sturdiness factor: the residuals F hand length (radius length) and F foot length (tibia length),

muscle factor: strength of hand grip,

fat factor: the residual F body-weight (stature, muscle factor).

The series was arbitrarily divided into three groups according to menarcheal age. Below, these groups are called the "early group" (menarcheal age 11–13 years), the "median group" (menarcheal age 14 years) and the "late group" (menarcheal age 15–18 years).

In the analysis of the fat factor two cases (belonging to the early group) were excluded because of obesity. The fat factors of those cases were +18.8 kg. (equal to +3.6 standard deviation units) and +26.5 kg. (equal to +5.1 standard deviation units) respectively. These two cases were also excluded in the analysis of the relationship between the bi-iliac breadth and other dimensions.

In order to calculate the significance of a difference between arithmetical means, the difference was tested by the *t-test* (Snedecor, '46). A difference found was considered statistically *significant* (**), if the probability of the difference being due to chance was less than 1%. If this probability was equal to, or greater than, 1%, but less than 5%, the difference was considered statistically *probable* (*).

TABLE 1

Different Body Measurements and Residual Expressions for Three Groups of Adult Females, Classified According to Menarcheal Age, and a Comparison Between the Body-Build and Early and Late Menarche

	MEASUREMENT OR RESIDUAL EXPRESSION	MENARCHEAL AGE 11–13 YEARS (87 cases)		MENARCHEAL AGE 14 YEARS (90 cases)		MENARCHEAL AGE 15–18 YEARS (111 cases)		DIFFERENCE $M_1 - M_3$	
		$M_1 \pm \epsilon_{(M_1)}$	σ_1	$M_2 \pm \epsilon_{(M_2)}$	σ_2	$M_3 \pm \epsilon_{(M_3)}$	σ_3	Diff. $\pm \epsilon_{(diff.)}$	t
Length factor	Tibia length in cm.	36.7 ± 0.3	2.3	37.1 ± 0.2	2.1	37.5 ± 0.2	2.3	0.8 ± 0.3	2.4*
	Radius length in cm.	23.1 ± 0.1	1.2	23.1 ± 0.1	1.1	23.6 ± 0.1	1.1	0.5 ± 0.2	2.9**
Sturdiness factor	Mean of *F* hand length (radius length) and *F* foot length (tibia length) in standard deviation units	0.0 ± 0.1	1.0	−0.1 ± 0.1	0.8	+0.1 ± 0.1	0.8	0.1 ± 0.1	1.2
Muscle factor	Hand-grip strength in dynamometer units	34.5 ± 0.8	7.1	33.7 ± 0.7	7.0	34.4 ± 0.8	7.9	0.1 ± 1.0	0.1
Fat factor	*F* weight (stature, muscle factor) in kg.	+0.6 ± 0.6	5.2	−0.3 ± 0.5	5.0	−1.6 ± 0.5	5.6	2.2 ± 0.9	2.8**
Proportions	*F* radius length (tibia length) in cm.	−0.1 ± 0.1	1.0	−0.3 ± 0.1	1.0	+0.1 ± 0.1	0.8	0.2 ± 0.1	1.4
	F bi-iliac breadth (bi-acromial breadth) in cm.	0.0 ± 0.2	1.5	0.0 ± 0.1	1.2	+0.1 ± 0.1	1.2	0.1 ± 0.2	0.5
	F bi-iliac breadth (radius length) in cm.	−0.1 ± 0.2	1.5	−0.1 ± 0.1	1.3	0.0 ± 0.1	1.2	0.1 ± 0.2	0.5
Other measurements	Stature in cm.	162.2 ± 0.6	5.8	162.3 ± 0.5	4.9	163.4 ± 0.4	4.5	1.2 ± 0.8	1.6
	Body weight in kg.	61.1 ± 0.8	7.5	60.0 ± 0.7	6.3	59.8 ± 0.6	6.5	1.3 ± 1.0	1.3

M = arithmetic mean, $\epsilon_{(M)}$ = error of mean, σ = standard deviation, $\epsilon_{(diff.)}$ = error of difference, t = quotient between the difference and its error. All calculations were made with two decimals, here reduced to one.

RESULTS

The mean values of certain measurements and residual expressions were calculated for each one of the three menarcheal age groups. The result obtained are summarized in table 1.

DISCUSSION

Significant differences in magnitude of length and fat factors were found between the early and late groups. In the early group the length factor was smaller, while the fat factor was larger.

The differences between early and late groups in sturdiness and muscle factors did not reach the level of statistical probability. However, it should be pointed out that the median group had a smaller sturdiness factor than did the late group. That difference was statistically probable ($t = 2.0^*$), but the difference between the values of the sturdiness factor in the early and median groups was not ($t = 0.5$).

The relation of menarcheal age to body configuration was studied by Barker and Stone ('36), the body-build then being registered typologically according to Kretschmer. The results obtained by these authors suggested a tendency of females with an early menstrual onset to develop towards the pyknic type, and of females with a late onset to develop towards the leptosomatic type. These assumptions are supported by the results obtained in the present investigation, as, according to Lindegård ('53), the pyknic type corresponds to an individual with small long-bone lengths and relatively large amount of body-fat, and the leptosomatic type to an individual with large lengths of the long bones and a relatively small amount of body-fat.

The results of the present investigation indicate that, concerning the length, fat, and sturdiness factors, women with a relatively early menstrual onset tend to develop a more pronounced "feminine" adult body structure than do women with a relatively late onset.

In view of these findings the menarcheal age groups were analysed in regard to body build proportions which vary with sex.

The proportion between the radius and tibia lengths did not show even a probable difference between the early and late groups. However, in the median group the radius length was smaller in proportion to the tibia length than in the late group. This difference was significant ($t = 3.1^{**}$). The corresponding difference between the early and median groups was not even statistically probable ($t = 1.3$).

Thus, an analysis of the proportion between the radius and tibia

lengths also suggested that women with an earlier menarcheal age will develop a more pronounced " feminine " adult body-build than do women with a later onset of menstruation.

The proportion between the bi-iliac breadth and the bi-acromial breadth is a marked sex-characteristic. Further, Lindegård ('53) showed that the bi-iliac breadth in proportion to the long-bone lengths is larger in females than in males. In the present investigation, however, no differences were noted between the menarcheal age groups concerning these proportions.

SUMMARY AND CONCLUSION

A series of 288 Norwegian adult women was studied for any relationship between the age of menstrual onset and adult body structure. The results obtained indicate a tendency of individuals with an early menarcheal age to develop a more pronounced " feminine " adult body structure than do individuals with a late début of menarche. The menarche being an estrogen mediated phenomenon it might also be concluded that individuals with an early onset of the pubertal estrogen incretion tend to acquire a more " feminine " adult body build than do individuals in whom this onset is late.

ACKNOWLEDGMENT

Generous advice and criticism was offered by Dr. B. Lindegård.

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THE SEX RATIO OF NEONATAL DEATHS IN JAPAN

BY EIJI TAKAHASHI

Department of Hygiene and Public Health,
Hirosaki University, Japan

THE number of neonatal deaths by sex and age during 1941 and 1942 was published in "Japanese Vital Statistics" ('41, '42). Since World War II the statistics have been published annually. ("Japanese Vital Statistics," '47, '48, '49). The system of classification of cause of death was altered in 1950.[1] The present observation on the sex ratio of neonatal deaths by age and discussion of causes of death is therefore limited to 1941, 1942, and 1947–1949.

SEX RATIO OF NEONATAL DEATHS BY DAYS OF AGE

The sex ratio was expressed as the number of males per 100 females. In the calculation of age, deaths on the first day means deaths on the day the baby was born. The sex ratio of neonatal deaths was observed for the first 5 days, every 5 days from the sixth to the thirtieth day, and thereafter, monthly.

The sex ratio of deaths in the first and the second days is between 124–132 as is shown in figure 1. For deaths on the third day the sex ratio is the highest, and it shows almost 140–150. For deaths on the fourth day the ratio decreases and approaches that of the first or the second day. For deaths between the fifth day and the sixth-to-tenth days (1948-1949) or between the fifth day and the eleventh-to-fifteenth days (1941, 1942 and 1947) the ratio diminishes to under 120, but thereafter it usually shows a small rise to 120–130. And then, from about the end of the first month, the ratio falls gradually to the end of the first year.

[1] In Japan parents or relatives register births by notifying the proper authority.

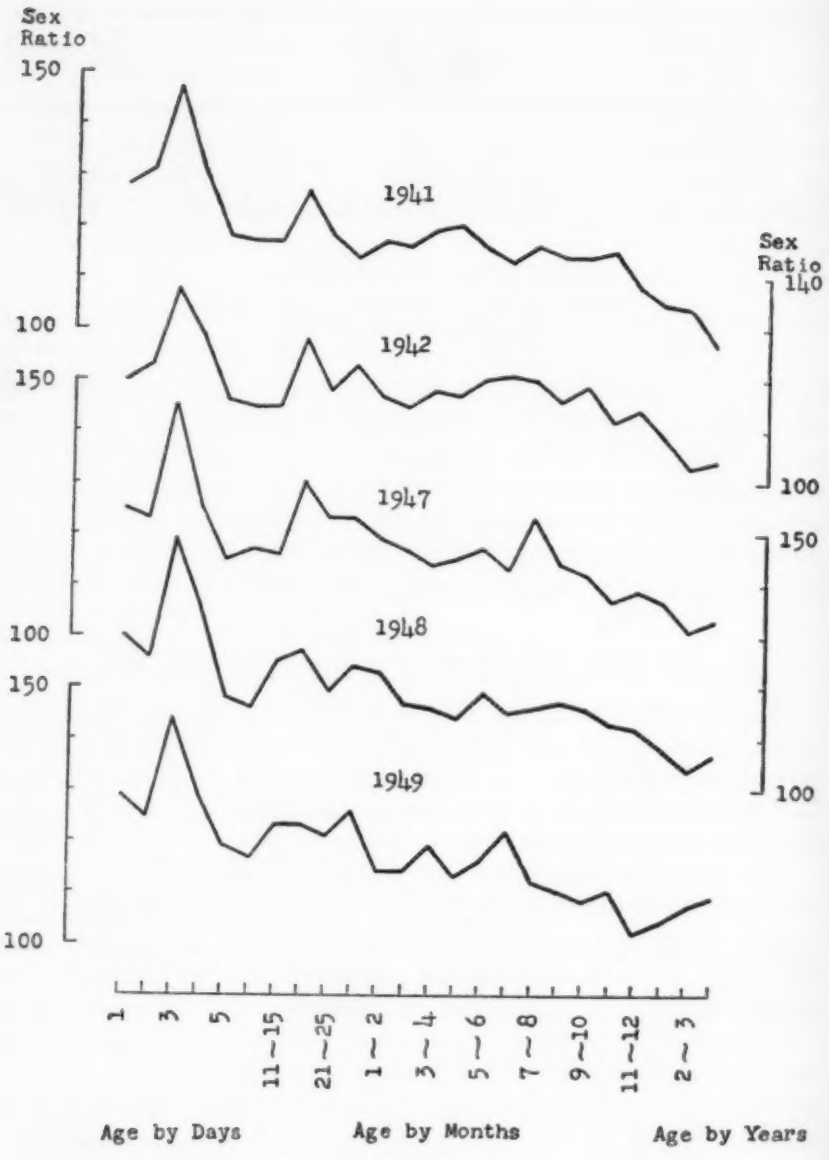

FIG. 1. SEX RATIO OF DEATHS OF INFANTS BY AGE IN DAYS AND MONTHS

Notwithstanding the fact that the sex ratio of infant deaths after the age of one month varies according to the current of the times, the sex ratio of neonatal deaths shows an almost constant, typical process. The most remarkable feature is the high sex ratio of deaths in the third day, which is shown also in Pfaundler's ('41) data. The calculation of the age by days is done by calendar age in the Japanese manner, therefore, deaths in the third day may include the deaths from 24 hours and a few minutes to about 72 hours.

SEX RATIO OF NEONATAL DEATHS BY DIFFERENT CAUSES

It might be expected, if there were a dominant cause of neonatal death with respect to one sex, that the high sex ratio of deaths in the third day would be effected by some specific cause.

The chief causes of neonatal deaths described in vital statistics of 1947-1949 are congenital debility, premature birth, congenital malformation, injury at birth and other diseases peculiar to the newborn and infants, as shown in figure 2. Pneumonia, bronchitis, diarrhea and enteritis, etc., are not as prominent as formerly as the cause of neonatal deaths, especially deaths in the first week.

The total number of deaths in the first day is smaller than in the second or in the third day, since the calculation is done according to calendar age. Congenital debility was always the cause of the most number of deaths in the first month, and the age distribution of deaths for congenital debility is most similar to that of deaths for all causes. The sex ratio of deaths for congenital debility has its peak in the third day, and there is a small rise in the latter half of the first month, as shown in figure 3. For premature births the number of deaths in the third day is not larger than that in the first or in the second day, and the sex ratio of deaths in the third day is not so high as in the first day. The age distribution of deaths for congenital malformation is similar to that for congenital debility, and the sex ratio of deaths for congenital malformation has also a curve similar to that for congenital debility until the end of the first year, but there is a considerable rise in the latter half of the first month. The number of deaths caused by injury at birth diminishes suddenly a few days after birth, but the sex ratio in the third day is the highest of all causes. The number of deaths for other diseases peculiar to the newborn and infants is larger in the third and the fourth days than in other days, and also, the sex ratio is higher in these days.

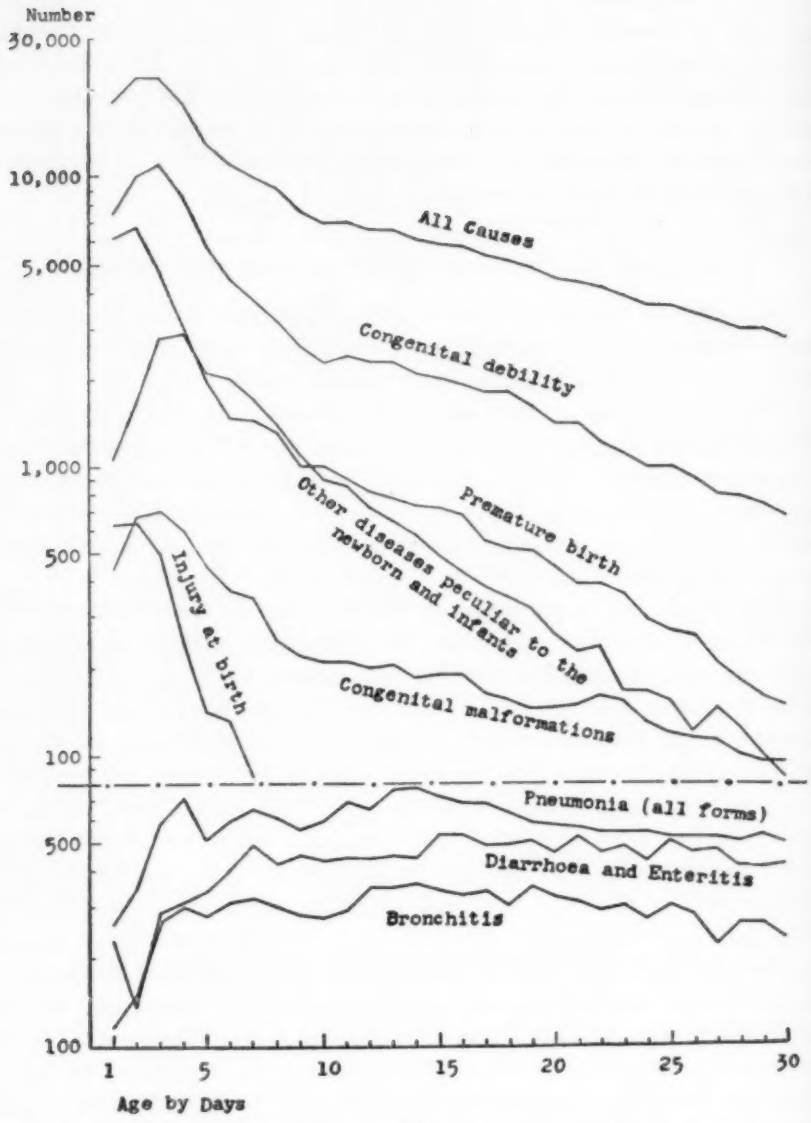

FIG. 2. NUMBER OF DEATHS OF NEWBORN UNDER ONE MONTH BY DAYS RELATED TO SELECTED CAUSES (TOTAL, 1947–49)

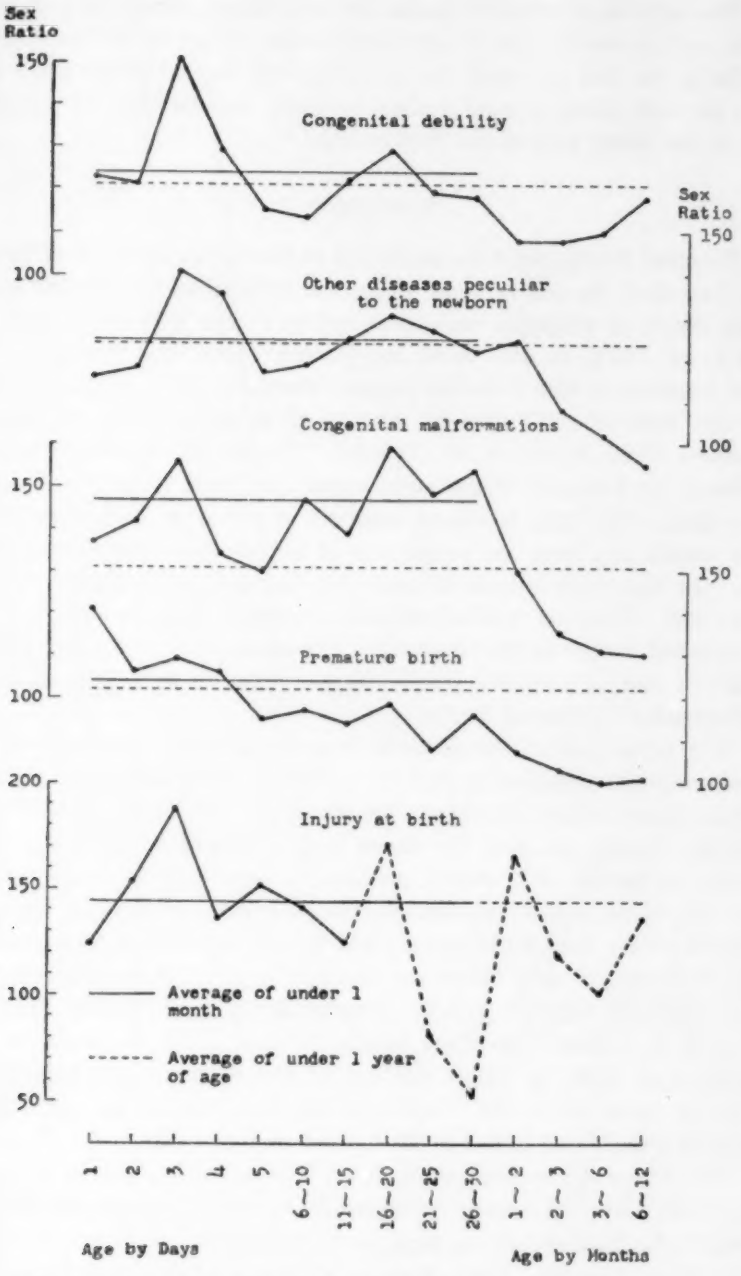

FIG. 3. SEX RATIO OF DEATHS OF INFANTS BY DAYS AND MONTHS RELATED TO SELECTED CAUSES, 1947–1949

The sex ratio of neonatal deaths for most causes, except for premature birth, save a similar type of age distribution. That is, the sex ratio of deaths in the first or second day is not as high as that in the third day; then the ratio shows a rapid decline for some days followed by a gradual rise in the latter half of the first month.

DISCUSSION

Neonatal deaths could be considered as the continuation of stillbirths. The fact that the sex ratio of stillbirths rises from the seventh to the ninth month of gestation was recognized by Ciocco ('38) and McKeown and Lowe ('51), in data from the United States and England. The same tendency is also found in Japan (Maruoka, '52). Figure 4 shows the sex ratio of stillbirths by months of gestation from the data of Japanese Vital Statistics of 1939-41. Though the sex ratio of stillbirths under 5 months of gestation seems very high, from 5 to 8 months of gestation the ratio is almost constant at 110–117; and from fetuses of 5 month and over, the percentage of sex unknown falls down under 1%. In the ninth month of gestation the ratio rises significantly to about 126. This sex ratio of stillborn fetuses is very near the sex ratio of neonatal deaths in the first day. The connection of the sex ratio of stillbirth and of neonatal death suggests that these deaths should be understood as perinatal deaths.

Why is the peak of the sex ratio of neonatal deaths in the third day? Here we might examine at first the influence of notification. Different certificates are required in Japan for stillbirths and for live births. Some who die during the first few hours may be listed as stillbirths (thus saving the bother of a second certificate), especially in rural districts. But this is no reason to conclude that the peak of the sex ratio is a cultural rather than a biological phenomenon, since there is no evidence that the deaths of male babies are reported more often as stillbirths than those of female babies. And the same tendency was found by Pfaundler ('42) in data from Bayern, as mentioned above. In the Japanese vital statistics of 1950, in which the age of the newborn was counted for every 24 hours as in the United States, the peak of the sex ratio of neonatal deaths was found in the second and third days.

The causes of neonatal deaths must be examined, although most neonatal deaths are not usually autopsied in Japan. "Congenital debility," which is highest of all causes of neonatal deaths in Japan, is not an exact cause of death. Most Japanese authorities think that "congenital

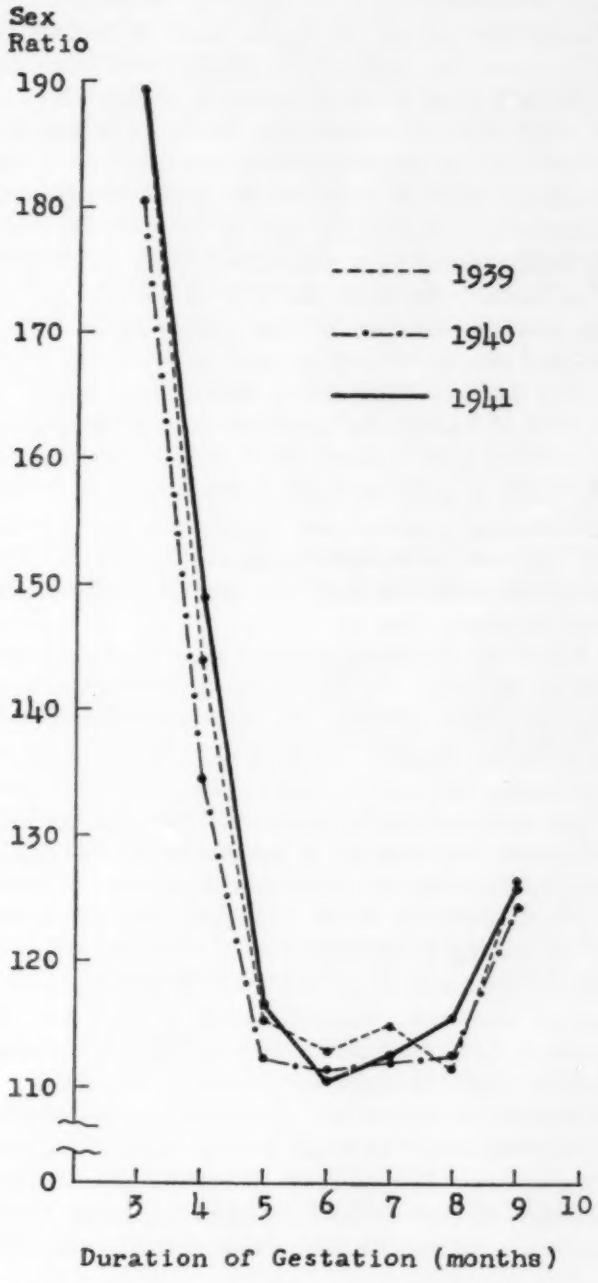

FIG. 4. SEX RATIO OF STILLBIRTHS RELATED TO DURATION OF GESTATION, JAPAN, 1939–1941

debility" must be absorbed in the category of "premature birth." But premature birth, also, is not the actual cause of neonatal deaths as Bundesen ('53) contends. Abnormal pulmonary ventilation seems to be the most important cause as he describes it, though this cause itself might be a result of more fundamental causes. (In this sense "congenital debility" should rather express a real condition.) Anyway, it might be recognized that the absence of the ability to adjust to the new environment at parturition is found more in males than in females. The sex ratio of deaths caused by "premature birth," which must usually be decided in Japan today from the term of parturition or from the weight of the newborn, does not increase sharply on the third day after birth. Therefore premature birth seems to have a qualitative difference from congenital debility. This fact is remarkable.

The diagnosis of "congenital malformation" is given more to those of the newborn who have apparent external malformations rather than to those who have no apparent malformations, because if there are no apparent malformations, internal malformations such as intestinal atresia etc., are not discovered, since most deaths of the newborn are not autopsied. It should be considered that such internal malformations may be included with congenital debility.

If it is a fact that lethal or sublethal genes in the sex chromosome, which manifests itself more in the male than in the female, are the real cause of neonatal deaths, as Lenz ('28, '52) hypothesized, then the high sex ratio of neonatal deaths in the third day might be explained. But, according to Ciocco ('38) and McKeown et al. ('51) the sex ratio of stillbirths for fetal malformation is the lowest. Especially in cases of stillbirth by congenital malformations of the central nervous system such as, anencephalus, spina bifida, etc., is the sex ratio very low as Record and McKeown ('49), McKeown et al. ('51) and MacMahon et al. ('53) recognized. According to MacMahon et al. ('51) in pyloric stenosis of the newborn the sex ratio is very high, but their data is not of deaths but of operated newborns. Since the onset of symptoms of infantile pyloric stenosis is distributed mostly between the first fortnight and the end of the first month, it might be considered that the second smaller rise of neonatal deaths during this period should have some relation to infantile pyloric stenosis. It seems that in Japan today, the chances of diagnosing and operating on cases of infantile pyloric stenosis is less than in England. If there is any congenital obstruction in the digestive tract, the newborn do not live over a few days after birth in the new

environment without operative treatment (Sweetnam et al., '53). Such congenital obstruction might be considered as a cause of the high sex ratio of neonatal deaths in the third day.

"Injury at birth" is a frequent cause of neonatal death, and the sex ratio of neonatal deaths for this cause is the highest in the third day. The cause of the high sex ratio has some similarity with difficult labor as the cause of stillbirths. As the cause of high sex ratio of neonatal deaths for injury at birth, the sexual differences of physical development of the new born might be considered. It might be comprehensible that the male should be injured more by parturition than the female, since the male fetus is, on the average, larger than the female. According to the statistics of 62,000 births from a district in Japan in 1949-50 (Tokano, '51), the body weight of the males is 3065.9 ± 2.2 gm and of the females 2988.3 ± 2.2 gm. But it is questioned whether or not a sexual difference of 77.6 gm could be the cause of the extraordinarily high sex ratio of neonatal deaths in the third day, caused by injury at birth.

It is believed that at present we lack sufficient data to explain the sex ratio of Japanese neonatal deaths in the third day and in the days following.

SUMMARY

The sex ratio of neonatal deaths in Japan in 1941, 1942 and 1947-49 was observed by age and by chief causes from government vital statistics data.

The sex ratio of neonatal deaths in the first and second days is near the sex ratio of stillbirths in the ninth month of gestation. The sex ratio of deaths in the third day is the highest, being almost 140–150. In the fourth day and thereafter the ratio decreases and reaches its lowest point between the fifth and the sixth-to-tenth or the eleventh-to-fifteenth days. Thereafter to the end of the first month, the ratio shows a small rise.

The third day's rise of the sex ratio of neonatal deaths, the decline afterwards, and then the small rise in the latter half of the first month were apparent in every chief cause except for premature birth; namely, for congenital debility, congenital malformations, other diseases peculiar to the newborn and infants, and injury at birth.

In order to explain the reasons why the sex ratio of neonatal deaths has this type of progress, we need more data.

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APPENDIX TABLE 1

Number and Sex Ratio of Neonatal Deaths in Japan

AGE	1941 MALE	1941 FEMALE	1941 SEX RATIO	1942 MALE	1942 FEMALE	1942 SEX RATIO	1947 MALE	1947 FEMALE	1947 SEX RATIO	1948 MALE	1948 FEMALE	1948 SEX RATIO	1949 MALE	1949 FEMALE	1949 SEX RATIO
1 Days	4,393	3,431	128.0±2.92	3,957	3,281	120.7±2.85	3,167	2,522	125.6±3.35	3,553	2,717	130.8±3.33	3,439	2,655	129.5±3.34
2	4,451	3,374	131.9±3.01	4,181	3,389	123.4±2.85	4,593	3,705	124.0±2.73	4,077	3,217	126.7±2.99	3,972	3,167	125.4±2.99
3	4,578	3,112	147.1±3.41	4,116	2,978	138.2±3.32	4,902	3,370	145.5±3.25	4,477	3,001	149.2±3.52	4,272	2,951	144.8±3.46
4	3,334	2,530	131.8±3.47	3,227	2,500	129.1±3.43	3,755	2,994	125.4±3.07	3,372	2,468	136.6±3.62	3,345	2,579	129.7±3.40
5	2,287	1,935	118.2±3.65	2,213	1,894	116.8±3.65	2,642	2,297	115.0±3.28	2,327	1,968	118.2±3.62	2,397	2,001	119.8±3.92
6-10	7,815	6,657	117.4±1.96	7,752	6,685	116.0±1.93	9,163	7,808	117.4±1.81	8,081	6,949	116.3±1.90	7,768	6,602	117.7±1.97
11-15	5,591	4,748	117.8±2.32	5,538	4,808	115.2±2.26	6,584	5,657	116.4±2.11	5,671	4,521	125.4±2.50	5,538	4,481	123.6±2.48
16-20	4,469	3,493	127.9±2.89	4,512	3,520	128.2±2.88	5,552	4,261	130.3±2.65	4,607	3,617	127.4±2.83	4,398	3,571	123.2±2.77
21-25	3,526	2,986	118.1±2.93	3,514	2,974	118.2±2.94	4,194	3,384	123.9±2.86	3,411	2,843	120.0±3.04	3,423	2,818	121.5±3.09
26-30	2,723	2,376	114.6±3.22	2,831	2,300	123.1±3.45	3,264	2,646	123.4±3.23	2,607	2,094	124.5±3.65	2,744	2,168	126.6±3.63
Subtotal	43,167	34,642	124.6±0.90	41,843	34,329	121.9±0.89	47,816	38,644	123.8±0.85	42,183	33,395	126.3±0.92	41,296	33,993	125.1±0.92
1- 2 Mos.	12,915	10,945	118.0±1.53	12,666	10,773	117.6±1.54	13,927	11,645	119.6±1.50	10,860	8,810	123.3±1.76	11,357	9,940	114.3±1.57
2- 3	8,068	6,906	116.8±1.91	7,982	6,900	115.7±1.90	8,665	7,404	117.0±1.85	6,673	5,663	117.8±2.13	7,161	6,261	114.4±1.98
3- 6	15,064	12,669	118.9±1.43	15,525	13,088	118.6±1.40	15,325	13,255	115.6±1.37	12,245	10,469	117.0±1.56	12,636	10,823	116.7±1.53
6-12	25,041	21,970	114.0±1.05	25,804	21,982	117.4±1.07	25,828	22,789	113.3±1.03	18,775	16,262	115.4±1.23	18,896	16,962	111.4±1.17
Total	104,255	87,132	119.6±0.55	103,820	87,072	119.2±0.55	111,561	93,737	119.0±0.53	90,736	74,599	121.6±0.59	91,346	76,979	118.7±0.58

N. B. Standard error of sex ratio $= R\sqrt{\frac{N}{PQ}}$, R : sex ratio, P : number of males, Q : number of females, N = P + Q.

APPENDIX TABLE 2

Number and Sex Ratio of Neonatal Deaths by Selected Causes in 1947-49 in Japan

AGE	ALL CAUSES MALE	ALL CAUSES FEMALE	ALL CAUSES SEX RATIO	CONGENITAL DEBILITY MALE	CONGENITAL DEBILITY FEMALE	CONGENITAL DEBILITY SEX RATIO	PREMATURE BIRTH MALE	PREMATURE BIRTH FEMALE	PREMATURE BIRTH SEX RATIO	CONGENITAL MALFORMATION MALE	CONGENITAL MALFORMATION FEMALE	CONGENITAL MALFORMATION SEX RATIO	OTHER DISEASES PECULIAR TO THE NEWBORN & INFANTS MALE	OTHER DISEASES PECULIAR TO THE NEWBORN & INFANTS FEMALE	OTHER DISEASES PECULIAR TO THE NEWBORN & INFANTS SEX RATIO	INJURY AT BIRTH MALE	INJURY AT BIRTH FEMALE	INJURY AT BIRTH SEX RATIO
1 Days	10,159	7,894	128.7±1.93	4,190	3,387	123.7±2.85	3,678	2,602	141.4± 3.62	259	188	137.8±13.20	574	491	116.9± 6.14	354	285	124.2± 9.88
2	12,642	10,089	125.3±1.67	5,916	4,889	121.0±2.34	3,801	3,001	126.7± 3.09	396	278	142.4±11.14	941	793	118.7± 5.60	391	253	154.5±12.47
3	13,651	9,322	146.4±1.96	6,696	4,413	151.7±2.94	2,729	2,108	129.5± 3.75	427	273	156.4±12.12	1,651	1,168	141.4± 5.40	329	174	189.1±17.72
4	10,472	8,041	130.2±1.93	4,890	3,767	129.8±2.81	1,734	1,374	126.2± 4.56	348	259	134.4±10.89	1,680	1,228	136.8± 5.13	142	105	135.2±17.36
5	7,366	6,266	117.6±2.34	3,128	2,717	115.1±3.02	1,109	962	115.3± 4.96	259	199	130.1±12.27	1,285	1,094	117.5± 4.71	85	56	151.8±26.11
6-10	25,012	21,359	117.1±1.09	8,839	7,763	113.9±1.77	3,422	2,915	117.4± 2.96	843	571	147.6± 7.85	3,883	3,261	119.1± 2.83	223	158	141.1±14.66
11-15	17,793	14,659	121.4±1.12	6,165	5,020	122.8±2.33	2,122	1,860	114.1± 3.62	596	402	139.3± 8.99	1,845	1,466	125.9± 4.40	93	75	124.0±19.21
16-20	14,557	11,449	127.1±1.59	4,894	3,774	129.7±2.80	1,485	1,239	119.9± 4.61	493	309	159.5±11.55	1,001	763	131.2± 6.17	57	33	172.7±37.76
21-25	11,028	9,045	121.9±1.73	3,207	2,684	119.3±3.12	898	828	108.5± 5.11	425	287	148.1±11.86	542	426	127.2± 8.24	16	20	80.0±26.83
26-30	8,615	6,908	124.7±2.01	2,126	1,793	118.6±3.68	519	447	116.1± 7.49	319	206	154.9±13.75	324	264	122.7±10.17	13	25	52.0±17.26
Subtotal	131,295	105,032	125.0±0.52	50,051	40,207	124.5±0.83	21,497	17,336	124.0± 1.26	4,365	2,972	146.9± 3.49	13,726	10,954	125.3± 1.60	1,703	1,184	143.8± 5.43
1- 2 Mos.	36,144	30,395	118.9±0.93	5,726	5,270	108.6±2.07	1,110	1,033	107.5± 1.46	1,102	843	130.7± 5.98	767	612	125.3± 6.66	55	33	166.7±36.66
2- 3	22,499	19,328	116.4±1.13	2,416	2,232	108.2±3.17	279	269	103.7± 8.84	527	456	115.6± 7.39	258	238	108.4± 9.74	13	11	118.2±48.41
3- 6	40,206	34,547	116.4±0.85	3,107	2,813	110.5±2.87	173	173	100.0±10.72	948	853	111.1± 5.13	302	295	102.4± 8.79	17	17	100.0±33.29
6-12	63,499	56,013	113.4±0.66	2,721	2,296	118.5±3.36	90	89	101.1±46.77	867	865	100.2± 4.71	189	198	95.5± 9.68	26	19	136.8±41.27
Total	293,643	245,315	119.7±0.33	64,021	52,818	121.2±0.71	23,149	18,900	122.5± 1.19	7,809	5,989	130.4± 2.23	15,242	12,297	123.9± 1.50	1,814	1,264	143.5± 5.24

DIFFERENTIALS IN INFANT MORTALITY BY RACE, ECONOMIC LEVEL AND CAUSE OF DEATH, FOR DETROIT: 1940 AND 1950

BY ALBERT J. MAYER AND RICHARD V. MARKS

Wayne University and Commission on Community Relations, Detroit

THE wastage of human life has been drastically reduced in those portions of the world where medical and allied sciences have been applied. The greatest progress has been made in the reduction of infant mortality. The unchecked rate of infant mortality is not only high, but extremely variable from year to year, ranging from one-tenth to one-half of all infants born. When infant mortality is controlled as it is in the United States, Western Europe, Australia, and New Zealand, the rate is low, ranging from 20 to 50 per thousand live births, and it fluctuates very little.

The City of Detroit can be classified as an area of very low infant mortality. In 1940 the infant mortality rate in Detroit was 37.43 deaths per thousand live births, while in 1950 it was 27.02 deaths per thousand live births.

Is there a still lower level to which infant mortality may fall, within the framework of existing medical knowledge and practice? This question is immediately answerable, for not only do a number of other places show smaller infant mortality rates,[1] but some groups in Detroit had smaller infant mortality rates in 1950 than the Detroit average. A number of previous studies have shown that infant mortality rate is inversely related to economic level, and that white persons have lower infant mortality rates than nonwhite persons (Collins, '27; Gover, '46; Green, '39; Wiehl, '48; and Woodbury, '25).

[1] Examples of countries having low infant mortality rates in 1950 are: Sweden, 20.5; Iceland, 21.7; New Zealand, 22.7; Australia, 24.5 (United Nations, '52).

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In this study, infant mortality rates have been calculated separately for three economic levels and for white and nonwhite persons within each economic level. The total rate has been further subdivided by cause of death, and these causes have been regrouped under three major rubrics: prematurity, physiological causes, and environmental causes. The precise composition of each of these groupings will be explained presently. Data for 1940 and 1950 are shown to illustrate the trend.

THE DATA AND METHOD

Our object was to measure as accurately as possible the forces of mortality in the first year of life. This meant a departure from the usual procedure of relating deaths in a calendar year to births in that year. Instead, the births of 1940 and 1950 were related to deaths of infants born during these two years and dying within the calendar year, with the addition of deaths of infants born in 1940 or 1950 and dying in 1941 and 1951 respectively, and the removal of infants born in 1939 and 1949, but dying in 1940 and 1950. Thus, a better approximation of the true probability of death under one year of age was obtained. The probability of death in the first year of life approximates the usual infant mortality rate sufficiently closely under relatively stable mortality and fertility conditions to be roughly comparable, although the two measures are not identical in the strict sense.

The birth and death data were secured from the Detroit Department of Health and are assumed to be very close to a 100% registration Births and deaths of non-Detroiters were eliminated, and births and deaths of Detroiters occurring in the 4 immediately contiguous counties in Michigan were added. The certificates of the Michigan State Department of Health were used for this purpose. Births and first-year deaths for 1940 totalled 27,141 and 1,016 respectively, while in 1950 these figures were 41,678 births and 1,127 first-year deaths. These totals are slightly below those published in the official reports of the National Office of Vital Statistics, for the reason that some births and deaths occurred outside the 4-county area. However, there is no reason to believe that these few additional births and deaths would significantly change the over-all rates.

The births and deaths were tabulated separately for white and nonwhite persons, for three broad economic levels based on rentals in the census tract in which the registered individuals lived, and for cause of death.

The method of measuring economic level was comparatively crude, but the major object was to illustrate broad patterns, rather than precise differences. Each birth and death was assigned to a census tract. The census tracts were then grouped into three economic levels by the median monthly rental given in the 1940 census; the class intervals were simply the upper, middle, and lowest thirds of the census tracts arrayed from highest to lowest rental. The same tracts were ascribed to each economic level in 1940 and 1950, the assumption being that the overwhelming majority of census tracts do not change in economic character in a ten-year period. The resulting three economic levels should not be considered as economic or social classes, but only as arbitrary groupings designed to show the presence or absence of an economic gradient. Data for white and nonwhite persons are shown separately by economic level. Although the cash rental levels are equivalent, one cannot assume that the economic level of white and nonwhite persons paying the same rent are equivalent, as nonwhite persons usually pay a larger portion of their total income for rent.

The *Sixth Revision of the International Lists of Diseases and Causes of Death* is currently used by the Detroit Department of Health. Every effort was made to keep the nine pathological categories exactly comparable for the two time periods, 1940 and 1950, since the *Fifth Revision of the Manual of the Causes of Death* was used to code the causes of death in 1940. There were modifications of classifications which affected the definition of causes of infant deaths, but since the Detroit Health Department uses the " intermediate code of the Sixth Revision," the problems created were minimal.

Working from the complete list of causes, we were able to divide all causes of infant deaths into 4 basic groups, " respiratory," " gastro-intestinal," " of early infancy," and " all other." Since this classification was not sharply enough defined for our purposes, we separated all deaths due to prematurity from the " early infancy " group and made prematurity one major category. Next, we took the " congenital malformations," and " all other diseases of early infancy " and made a second major category of causes which we called physiological. In this group we included those deaths of infants from the former " all other " category which were related to a physiological cause, where the condition giving rise to the death arose within the organism. Finally, we united the " gastro-intestinal " causes and the " respiratory " causes, and added the group of " accidental " infant deaths and " birth injury," as well as the

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deaths called "all other—environmental," where the cause of death arose from a condition which originated outside the organism. This third major category we called the environmental causes.

CHANGES IN THE INFANT MORTALITY RATE 1940-1950

Table 1 indicates the infant mortality rates for the population in general in 1940 and 1950. In 1950 infant deaths from all causes were only 72% of the 1940 level. The greatest reduction occurred in the category of environmental causes. In 1940 there were 12.60 deaths per thousand infants in the environmental group, and in 1950, 7.27 deaths per thousand infants, only 58% of the 1940 rate. Within certain subcategories of the environmental category even more marked changes occurred.

TABLE 1

Infant mortality rates by cause, Detroit: 1940 and 1950 [1]

	1940		1950		
	(1) Rate	(2) Per cent	(3) Rate	(4) Per cent	Col. (3) / Col. (1)
Total	37.43	100.0	27.02	100.0	.72
PHYSIOLOGICAL CAUSES	11.31	30.2	8.93	33.0	.79
Congenital Malformation	5.78	15.4	4.92	18.2	.85
Other Causes of Death in Early Infancy	3.43	9.2	3.17	11.7	.92
All Other, Physiological	2.10	5.6	.84	3.1	.40
PREMATURITY	13.52	36.1	10.82	40.0	.80
ENVIRONMENTAL CAUSES	12.60	33.7	7.27	27.0	.58
Respiratory	4.68	12.6	2.28	8.5	.49
Gastro-Intestinal	1.88	5.0	.77	2.8	.41
Accidents	.55	1.5	.62	2.3	1.13
Birth Injuries	3.83	10.2	3.17	11.8	.83
All Other, Environmental	1.66	4.4	.43	1.6	.26

[1] In this and succeeding tables only the rates per thousand are shown. The number of deaths upon which each rate is based can be computed, for the denominator is always 27,141 births in the case of the 1940 rates, and 41,678 births in the case of the 1950 rates.

"Gastro-intestinal" and "respiratory" causes of infant death were reduced to 41% and 49% of their 1940 levels respectively. The category

"all other" was only 26% of its 1940 level in 1950. The latter probably reflects, among other things, improvements in the degree of care taken when filling out and coding death certificates.

Death rates in two of the major groupings, those of physiological causes and of prematurity, also were reduced in this decade. Each declined to about four-fifths of its 1940 level. Considering that some infants are born, live long enough to breathe, and yet are so grossly malformed or so premature that sustained life is highly improbable, the decline of the infant mortality rate in these categories during the 1940-1950 period reflects a high standard of medical case. There doubtless will be even more improvement in medical techniques in the future, especially in those related to saving the lives of premature infants.

Regarding the proportion of all deaths in 1940, in each of the major categories, deaths due to environmental causes comprised 34% of all deaths in the first year of life, whereas in 1950 they were only 27%.

The purpose of the remaining sections of this paper is to analyze the share of the various groups in the population in the general reduction in infant mortality.

WHITE AND NONWHITE POPULATION

Nonwhite persons have always been at a disadvantage compared to white persons in receiving health and medical care. Their life expectancy has been lower, and above all, their infant mortality rate has been markedly higher than white persons living in the same geographic area.

This phenomenon was evident in Detroit in the past and it still prevails. In 1930, deaths among nonwhite infants were 90 per thousand live births, while among white infants there were 62 deaths per thousand live births. This is a ratio of 1.45 deaths among nonwhites to one death among whites. There has been little change in the relative positions of white and nonwhite persons in this respect in the past 20 years. A considerable decline (from 90 to 35 per thousand in the nonwhite population, and from 62 to 25 per thousand in the white population) occurred, but infant death rates for nonwhite persons were still about 40% higher than for whites after 20 years. This might be ascribed to constitutional or genetic differences, inasmuch as the difference between races has remained almost constant. However, division of the causes of death into the major categories suggests other interpretations.

In 1940 environmental causes of death and death from prematurity were substantially higher among nonwhite persons than among white

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TABLE 2

Infant mortality rates by race and cause, Detroit: 1940 and 1950

	1940			1950		
	(1) White	(2) Nonwhite	Col. (2) / Col. (1)	(3) White	(4) Nonwhite	Col. (4) / Col. (3)
Total	35.86	52.30	1.46	25.06	35.40	1.41
PHYSIOLOGICAL	11.45	10.00	.87	8.56	10.49	1.23
Congenital Malformation	6.07	3.08	.51	5.18	3.79	.73
Other Causes of Early Infancy	3.42	3.46	1.01	2.67	5.31	1.99
All Other, Physiological	1.96	3.46	1.77	.71	1.39	1.96
PREMATURITY	12.67	21.54	1.70	10.39	12.52	1.21
ENVIRONMENTAL	11.74	20.76	1.77	6.11	12.39	2.03
Respiratory	4.28	8.46	1.98	1.74	4.55	2.61
Gastro-Intestinal	1.96	1.15	.59	.65	1.26	1.94
Accidents	.57	.38	.67	.56	.89	1.59
Birth Injuries	3.55	6.54	1.84	2.75	4.93	1.79
All Other, Environmental	1.38	4.23	3.07	.41	.76	1.85

persons. The death rate from physiological causes was actually lower among nonwhite persons than among white persons. In the category of environmental causes, most of the difference was concentrated in deaths from respiratory diseases and birth injuries. By 1950 the picture had shifted considerably, although the over-all proportion was about the same. But whereas the rate for white infants declined only 2.28 per thousand in 10 years, the decline in rate for nonwhites was 9.02 per thousand. Several factors might explain this substantial difference between races in the reduction in frequency of death of premature infants. First, some infants are just too undeveloped at birth to live more than a few hours or days. As the rate of prematurity for white infants was already quite low in 1940, there was less room for improvement during the decade. Therefore, given the present level of medical knowledge, the white population had fewer "preventable" deaths of premature infants.

The second factor is that a premature baby gets practically the same

care regardless of color, or economic level of the parents, provided it is born in a hospital. In 1950, 97.5% of all infants born in Detroit were born in hospitals, while in 1940 only 77.3% were born in hospitals. Thus, equal levels of care were available to more persons, and differentials in the death rates from prematurity declined markedly.

Substantial differences were observed in the relative positions of white and nonwhite infant death rates between 1940 and 1950 in the environmental category. The rates for white persons declined more than the rates for nonwhite persons. Death from "respiratory," "gastrointestinal," and "accidental," causes were proportionately greater among nonwhite infants as compared with white infants. One plausible explanation for this is that in the decade 1940-1950, the nonwhite population of Detroit increased 100% while the white population increased only 5%. The majority of the migrants were from the rural South where standards of infant care are greatly below those found in large urban centers in the north. It is highly possible that many of the migrants who gave birth to a baby which subsequently died in its first year of life, may have had little awareness of facilities available for infant care. Also family disorganization, so frequent among migrants, may have mitigated against full use of these facilities.

ECONOMIC DIFFERENCES IN THE WHITE POPULATION

When infant mortality from all causes is examined, it is seen that there was a distinct economic gradient in both 1940 and 1950 (table 3). That is, the most favored economic group (Economic Group #3) had the lowest infant mortality rate, the middle economic group (Economic Group #2) the middle rate, and the lowest economic group (Economic Group #1) the highest rate. Also, the relative position of the three economic groups with respect to one another, changed little in the course of the decade. As previously noted, the infant mortality rate for the total population in Detroit in 1950 is characterized as low, yet as the rate of 21.82 per thousand in Economic group #3 indicates, still further improvement may be expected in the future if the two lower economic groups, as in the past, equal the standards attained by the highest economic group a few years previously.[2]

[2] The factor of mother's age is frequently associated with infant mortality. While we do not have direct evidence on infant mortality by birth order or age of mother, births, tabulated by age of mother, indicate that the median age of

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TABLE 3

Infant mortality rates for the white population by economic level and cause, Detroit: 1940 and 1950

	(1) Economic Group 1	(2) Economic Group 2	(3) Economic Group 3	Col. (1) / Col. (3)	Col. (2) / Col. (3)
1950					
Total	28.11	25.95	21.81	1.29	1.19
PHYSIOLOGICAL	8.75	8.82	8.10	1.08	1.09
Congenital Malformation	5.60	5.66	4.31	1.30	1.31
Other Causes of Early Infancy	2.57	2.50	2.93	.88	.85
All Other, Physiological	.58	.66	.86	.67	.77
PREMATURITY	11.66	11.75	8.45	1.38	1.33
ENVIRONMENTAL	7.70	5.88	5.27	1.46	1.12
Respiratory	2.45	1.69	1.29	1.90	1.31
Gastro-Intestinal	.70	.74	.52	1.35	1.42
Accidents	.70	.51	.52	1.35	.98
Birth Injuries	3.15	2.43	2.85	1.11	.85
All Other, Environmental	.70	.51	.09	7.78	5.67
1940					
Total	41.20	34.87	31.85	1.29	1.09
PHYSIOLOGICAL	12.85	10.13	11.91	1.08	.85
Congenital Malformation	6.43	5.51	6.51	.99	.85
Other Causes of Early Infancy	3.63	2.85	4.02	.90	.71
All Other, Physiological	2.79	1.77	1.38	2.02	1.28
PREMATURITY	11.87	14.07	11.49	1.03	1.22
ENVIRONMENTAL	16.48	10.67	8.45	1.95	1.26
Respiratory	6.15	4.23	2.49	2.47	1.70
Gastro-Intestinal	3.07	1.77	1.11	2.77	1.59
Accidents	.70	.49	.55	1.27	.89
Birth Injuries	4.05	2.95	3.88	1.04	.76
All Other, Environmental	2.51	1.23	.42	5.98	2.93

white mothers in the highest economic group was only 1.4 years higher than mothers in the lowest economic group in 1950, and 2.6 years in 1940. Among nonwhite mothers, age differences between economic groups were less than .4 of a year in both 1940 and 1950.

In the category of physiological causes, in both years, the usual inverse relationship between economic level and infant mortality did not hold. The differences that did occur were very small. What further reductions may occur in the future it is difficult to say. A few deaths from these causes should always occur. Yet in each of the economic groups, there was a smaller infant death rate from physiological causes in 1950 than in 1940, and it is probable that further reductions in rate will take place.

The category of deaths caused by prematurity contains some particularly noteworthy relationships. In 1940, the middle economic group had the highest death rate from prematurity (14.07). This again is an instance where the inverse relationship between infant mortality and economic level did not obtain. The same relationship has been previously observed in a similar study conducted by one of the authors in Chicago (Mayer, '50). There, as in Detroit, white infants in the lowest economic group in 1940 had a lower rate of mortality due to prematurity than infants in the next lowest economic group. In 1950, in Detroit the middle economic group again had the highest rate of deaths from prematurity, but the difference between it and the lowest economic group was too small to permit conclusions. In the highest economic group the rate of prematurity was distinctly smaller, 8.45 in 1950 compared with 11.49 in 1940. This indicates a new level of attainment. If the pattern of the past continues, deaths from prematurity in the lowest and middle economic groups will decrease in the future and reach the level of the highest economic group today, and the rate for the highest economic group will continue to decline even further.

In all economic groups, the deaths from environmental causes are becoming fewer. Even in the short space of 10 years, major gains are evident. In 1950, the lowest economic group had a smaller infant death rate from environmental causes than the highest economic group 10 years previously. Also, the differences between the three economic groups were less in 1950 than in 1940.

ECONOMIC DIFFERENCES IN THE NONWHITE POPULATION

In 1940, the total infant mortality rate in the nonwhite population was greater in the high economic group (Economic group #2). Analysis by cause indicates this was due to a higher rate in the prematurity category. While the rate for prematurity in the lower economic level of nonwhite population in 1940 was 17.68, the rate for the higher economic

level among nonwhite persons was 31.55. A possible explanation of this relation, as well as the similar observation in the white population, lies in the greater expenditure of social welfare efforts on the poorest persons in the community. Another related possibility is the reluctance of persons, not in actual poverty, to seek the services of welfare and charitable agenices, thereby exposing themselves (in this case their unborn infants) to paid, but medically inferior services.

TABLE 4

Infant mortality rates for the nonwhite population by economic level and causes Detroit: 1940 and 1950

	(1) Economic Group 1	(2) Economic Group 2	Col. (1) / Col. (2)
1950			
Total	37.31	32.94	1.13
PHYSIOLOGICAL	11.03	10.49	1.05
Congenital Malformation	3.81	4.12	.92
Other Causes of Early Infancy	5.82	4.87	1.20
All Other, Physiological	1.40	1.50	.93
PREMATURITY	12.84	11.61	1.11
ENVIRONMENTAL	13.44	10.84	1.24
Respiratory	4.61	4.49	1.03
Gastro-Intestinal	1.81	.37	4.89
Accidents	1.20	.37	3.24
Birth Injuries	4.82	5.24	.92
All Others, Environmental	1.00	.37	2.70
1940			
Total	51.98	53.50	.97
PHYSIOLOGICAL	11.25	6.85	1.64
Congenital Malformation	3.75	1.37	2.74
Other Causes of Early Infancy	3.75	2.74	1.37
All Other, Physiological	3.75	2.74	1.37
PREMATURITY	17.68	31.55	.56
ENVIRONMENTAL	23.05	15.10	1.53
Respiratory	9.65	5.49	1.76
Gastro-Intestinal	1.61		
Accidents	.54		
Birth Injuries	7.50	4.12	1.82
All Other, Environmental	3.75	5.49	.68

In the physiological and environmental categories, the customary inverse relationship of mortality to economic status obtained. Comparing 1940 with 1950, it is seen that economic differentials were smaller in both categories, declining from a ratio of 1.64 in 1940 to 1.05 in 1950 in the category of physiological causes, and from 1.53 in 1940 to 1.24 in 1950 in the category of environmental causes. This could be expected as, with the exception of the rate of deaths from prematurity, the lower economic group had far higher rates of infant mortality than the higher economic group, and consequently there was more room for improvement.

THE GENERALITY OF THE FINDINGS

As the data examined here pertain to only one geographic area, the question might well be asked: how does the infant mortality rate in Detroit compare with that in other areas? Table 5 contains data comparing Detroit with the United States and with urban places within other states. The states selected for comparison were chosen for their high level of industrialization and of income. Together, these states contain 34% of the population of the United States.

TABLE 5

Infant mortality rates, Detroit, United States, and selected states by race: 1950 [1]

	INFANT MORTALITY RATE	
	White	Nonwhite
Detroit	25.1	35.4
United States	28.9	47.3
United States—Urban	27.8	46.0
Michigan	27.8	40.9
Michigan—Urban	26.9	39.2
New York	25.0	38.3
New York—Urban	24.8	38.5
Illinois	26.0	40.5
Illinois—Urban	26.3	40.2
Pennsylvania	27.8	47.2
Pennsylvania—Urban	27.2	47.3
California	26.2	34.0
California—Urban	24.5	32.7

[1] Data from Statistical Abstract of the United States ('53).

It is evident from the above table that the infant mortality rate among white persons in Detroit is slightly below the rate of the state of Michigan, while Michigan in turn is slightly below the United States as a whole. Comparison with other large industrial states indicates the representativeness of Michigan. In the nonwhite population the variation is somewhat larger, as the rate is higher and higher infant mortality rates are more variable. While the rates shown here suggest that Detroit is not atypical, generalization of the findings of this study, especially as to the effects of economic differentials, must be made with caution.

WHY STUDY INFANT MORTALITY IN AREAS WHERE THE RATE IS ALREADY LOW?

This study indicates that, where infant mortality has reached a low level, little in the way of a major decline in the rate can be expected in the future. While there is still room for improvement, and subsequent advances in medical science (especially in the care of premature infants) will undoubtedly take place, it is doubtful that medical and biological science can learn anything new from further epidemiological study. However, the study of infant mortality will, in the future as in the past, be important to the social scientist. The infant mortality rate has been considered an excellent index of the level of living of a population. This study indicates that, even when the infant mortality rate for a total population is low, as in Detroit today, there are still differences between various subgroups in the population. Although the differences are small, they are consistent. Very probably they will prove extremely persistent, and it may be many years until equally low infant mortality rates are attained by all groups residing in the same area. Until that time, the infant mortality rate can continue to be used as an index of the level of living of various subgroups of the population. Birth and infant death statistics are among the most precise and readily obtained social data, and can be conveniently used to classify groups of persons, or geographic areas in which such groups of persons reside.

SUMMARY

(1) Detroit has a low rate of infant mortality (27.02 per thousand live births in 1950). This is a marked decrease from the rate of 37.43 infant deaths per thousand live births in 1940.

(2) The largest reduction in infant mortality was found among those causes grouped under the general heading of "environmental

causes." About 51% of the total reduction of 10.41 per thousand represented a reduction in environmental causes.

(3) Although the infant mortality rates of both white and nonwhite infants declined markedly during the decade 1940-1950, the relative position of the nonwhites improved only slightly, changing from 46% higher than the whites in 1940 to 41% higher than the whites in 1950.

(4) Infant mortality rates in the white population of Detroit in both 1940 and 1950 were, as usual, inversely proportional to economic level. However, when subclassified by cause of death, the usual pattern did not apply in 1940, since the middle economic group had a higher rate of deaths due to prematurity than did either the highest or the lowest economic group. This was equally true in the nonwhite population. A greater use of social welfare facilities on the part of the lowest economic group is a suggested cause of this.

(5) Deaths from environmental causes reached very low levels in all white economic groups in 1950. Although slight economic differences persisted, the margin of difference between economic groups in the white population was less in 1950 than in 1940.

(6) In general, the relationship between similar economic groups in the nonwhite population was as in the white population.

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THE EFFECT OF BIRTH WEIGHT AND TIME OF FIRST FEED ON THE WEIGHT OF BANTU BABIES IN THE FIRST 10 DAYS OF LIFE

BY EVA SALBER[1] AND EVELYN BRADSHAW

Institute of Family and Community Health, Durban, Union of South Africa

THE weights of Bantu babies in the first 10 days of life, with special reference to rank order of birth, sex and marital status of mothers have been reported upon previously (Salber and Bradshaw, '53). In this paper we are concerned with the effect on their subsequent growth of (1) the birth weight of babies and (2) the time of first feed after birth.

MATERIAL AND METHOD

The same babies were used in this study as described in the previous paper, *i. e.* 598 full-term babies, born of normal vertex delivery, who were well during their stay in hospital. For this study it was necessary to have the birth weight of the baby, and also the time at which the baby was first put to the breast. Where this information was not available the cases were discarded, leaving us with 596 babies of known birth weight, and 577 babies whose time of first feed was recorded.

The babies were divided into three birth weight groups, *i. e.* 5 lb. 8 oz. to 6 lb. 7 oz., 6 lb. 8 oz. to 7 lb. 15 oz., and 8 lb. and over, and their progress was compared.

With regard to the time of first feed after birth, we planned to compare three groups, viz.: those fed as soon after birth as possible, those fed as late after birth as possible, and those in between. However, we soon found that this interfered with the hospital routine to a large

[1] Senior Bursar of the Council for Scientific and Industrial Research at the time the data for this study was collected and the analysis completed.

extent and, although it was possible to have babies fed soon after birth, it was extremely difficult to have the first feed delayed much longer than 10 hours. As a result the three feeding groups are:

1. Those fed within the first hour (59 minutes or less).
2. Those fed between 1 and 6 hours after birth (1 hour to 5 hours 59 minutes).
3. Those fed 6 or more hours after birth (6 hours or more).

The distribution of the times of the first feed in single hours is shown in appendix 1.

As in the previous paper, daily gains or losses from birth weight were calculated, also the total initial loss and the duration of loss. This was done for the three birth weight groups and the three feeding groups, sexes and ranks separately.

RESULTS

The effect of birth weight on loss of weight after birth

Mean daily loss in weight. Longridge ('05), Griffith and Gittings ('07) and Martin ('31) found that the heavier the baby, the more weight is lost. Hammett ('18) and Meredith and Brown ('39) found the loss for heavy infants to be both absolutely and relatively greater than for light infants, but Ramsey and Alley ('18) and Naish and Edwards ('52) found no difference in percentage weight loss.

Our babies were divided into three birth weight groups as previously stated, and will be referred to as light, average and heavy babies.

Since birth rank has a marked influence on weight loss after birth—first babies losing more weight than later born babies—Salber and Bradshaw ('53), we investigated separately first-born (Rank 1) and subsequently-born (Rank 2+). Our results show that the heavier babies tend to lose more weight, both actual and relative, than the light babies (appendix 2). Further, in Rank 1 the heavier babies lose for a day longer than the lighter babies. In Rank 2+, however, all the babies lost for the same time (two days) except for the light boys, who inexplicably lost for three days.

Total initial loss. As mentioned in the previous paper, not all the babies reached their minimum weight on the third day, and it was necessary to examine the mean amount of weight lost regardless of when this occurred. A decided difference in the total initial loss was found,

with the heavier babies losing more actual weight. This applied to both sexes, and to Ranks 1 and 2+ separately. The relative loss of weight, expressed as a percentage of birth weight, showed little difference between the birth weight groups, and these results were not consistent (appendix 3). The heavier babies lost for a slightly longer period, but the differences were very small (appendix 4).

The effect of birth weight on regain of weight

Hammett ('18) reported that "the lighter the initial weight, the earlier the recovery of weight loss." Martin ('31), however, found no difference in the weight gain of lighter or heavier babies. Meredith and Brown ('31) stated that the actual gain was more for light babies.

Gain. As some birth weight groups had no information after the seventh day, investigation into the weight gain had to be limited to the first 4 days after the day of minimum weight. Table 1 shows the actual

TABLE 1

Gain in 4 days from minimum weight

	RANK 1				RANK 2+			
	Girls		Boys		Girls		Boys	
	Amount	%	Amount	%	Amount	%	Amount	%
Birth Weight Groups:								
Light	1.74 oz	1.8	4.38 oz	4.6	3.76 oz	3.9	4.05 oz	4.2
Average	3.19 "	2.8	5.69 "	5.0	3.73 "	3.2	4.45 "	3.8
Heavy	—	—	—	—	3.53 "	2.4	4.89 "	3.6

amount of gain in those 4 days, and also the relative amount, as a percentage of birth weight. It can be seen that Rank 1 is quite consistent, and for both girls and boys average babies gain more actual and more relative weight than light babies. In Rank 2+ the picture is different—for both girls and boys the relative weight gain is greatest for the light babies and smallest for the heavy babies. In actual amount of gain, however, while the light girls gain the most, it is reversed for the boys, with the heavy babies gaining the most.

Return to birth weight by seventh day. The percentage of babies who had regained birth weight by the seventh day is the resultant of

1. The amount of weight lost.
2. The duration of that loss.
3. The rate of gain thereafter.

In Rank 1 girls a greater percentage of the light babies had regained their birth weight than the average babies, whereas for the boys there is a very slight difference in the opposite direction. In Rank 2+ the lighter girls again do very much better than the heavier girls, whereas the average boys do better than the rest. (See appendix 5).

Day on which group returned to birth weight. This is only applicable to Rank 2+ babies. (See appendix 2). Here again the light girls did better than the rest, for although both light and average babies had regained their birth weight by the eighth day, the light babies were 1.9 oz over birth weight, whereas the average girls were only .5 oz over birth weight. The average boys again did better than the other groups, regaining birth weight by the seventh day. As the groups in Rank 1 had not regained birth weight, we compared seventh day losses as a percentage of birth weight. In both girls and boys the light babies were closer to birth weight than the average babies.

The effect of birth weight, then, on loss and gain of weight after birth shows no clear pattern. Results vary both for the ranks and the sexes. We decided therefore, in an endeavor to obtain a clearer picture, to score the groups for the categories previously mentioned:

1. Day of maximum loss.
2. Amount of loss as a percentage of birth weight.
3. Total initial loss as a percentage of birth weight.
4. Duration of loss.
5. Gain in 4 days after minimum weight.
6. Percentage who regained birth weight by the seventh day.
7. Day on which group returned to birth weight.

Whichever group did best in each category was given one point, and in the event of two or three groups doing equally well, they each scored one point.

It is obvious from table 2 that the light girls do better than the others both in Rank 1 and Rank 2+. Light boys do better in Rank 1, but average boys do best in Rank 2+.

TABLE 2

Comparison of three birth weight groups with respect to various factors. Sexes and ranks separately.

	RANK 1														RANK 2+											
	Girls							Boys							Girls							Boys					
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Light	1	1	1			1	1	1	1	1	1			1	1	1	1	1	1	1	1				1	1		
Average				1	1						1		1	1	1							1	1	1	1		1	1
Heavy															1							1						

It is still a fact, however, that because of their superior birth weight, the heavy babies retain their lead (as far as actual weight is concerned) over the average and light babies on discharge from hospital.

The effect of time of first feed after birth on the progress of the babies

The three feeding groups (called hereafter early, middle and late) were examined with regard to loss and gain in weight in the same way as the birth weight groups were done. One of the 7 categories (gain in 4 days after minimum weight) was omitted because of insufficient data. (See appendices 3, 4, 5 and 6).

Mean daily loss in weight. In Rank 1 babies, the girls of the late feeding group lost less percentage weight than the middle group, with the same duration of loss (appendix 6; insufficient data for early feeders). In the boys, the middle feeders did better—both for percentage weight loss and duration of loss than the early feeders (insufficient data for late feeders). In Rank 2+, for both boys and girls the middle feeding group were best with regard to percentage loss of weight, and the middle and late feeding girls lost for a shorter period than the early feeding girls. However, the early feeding boys lost for the shortest time.

Total initial loss of weight. In Rank 1 the late feeding girls and the middle feeding boys did best, whereas in Rank 2+ the middle feeding girls and the early feeding boys did best. The duration of this loss of weight follows almost exactly the same pattern as the total initial loss (appendices 3 and 4).

Return to birth weight. In Rank 1 the middle feeding girls and boys, and in Rank 2+ the middle feeding girls and the early feeding

boys were superior in the percentage who had regained their birth weight by the seventh day (appendix 5). With regard to the day on which the group returned to birth weight, there was insufficient data for Rank 1. In Rank 2+ the middle feeding girls and the early feeding boys returned to birth weight soonest.

Here again the picture is not clear, and we followed the same scoring procedure as before, with the omission of the one criterion mentioned previously. Table 3 shows quite an interesting pattern: in Rank 1 it appears that late feeding girls and middle feeding boys progress most favorably, and the same applies to middle feeding girls and early feeding boys in Rank 2+.

TABLE 3

Comparison of three feeding groups, with respect to various factors. Sexes and ranks separately.

	RANK 1												RANK 2+											
	Girls						Boys						Girls						Boys					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
59 minutes or less																			1		1	1	1	
1–5 hours	1				1		1	1	1	1	1	1	1	1	1	1	1	1		1				
6 hours or more	1	1	1	1									1										1	

DISCUSSION

The birth weight of the baby and the time of first feed after birth have some effect on the progress of the baby in the first 10 days of life, although these factors are not nearly as strong as the factor of rank order.

The effect of birth weight on progress after birth is slight. With regard to mean daily loss of weight the heavier babies lose more actual and relative weight than the lighter babies, and on the whole for a longer period. The total initial loss is also greater for heavier babies, although the relative loss is much the same. As far as the effect of birth weight on gain after birth is concerned, the average Rank 1 babies gain the most relative and absolute weight. In Rank 2+ the light babies gain most relative weight, but the actual amount of weight gained varies for boys and girls. On the whole the light girls and the average boys returned to birth weight soonest, and a greater percentage of babies in these two groups had regained birth weight by the seventh day.

When each category was scored, the total progress picture showed

that for girls in Rank 1 and Rank 2+ the light babies did best. For boys differed with the ranks—light boys being better off in Rank 1 and average boys in Rank 2+.

As mentioned previously, although the heavy babies lose more weight, and do not gain as much as the light and average babies, they are still the heaviest group on discharge from hospital owing to their superior birth weight. Various investigators have studied the effect of birth weight on subsequent growth. Illingworth et al. ('49) found that throughout childhood the average child who was a small baby at birth weighed considerably less than the average child who at birth was a large baby. Lowe and Gibson ('53) stated that "the mean weight at the third birthday is closely related to the birth weight." Parfit ('51), however, points out that the actual amount of weight gain is the same for the different birth weight groups after the first month, and Hammond ('52) also found that birth weight appeared to have no effect on weight gain in the first year. This means, in effect, that heavier babies at birth remain heavier subsequently, but that smaller babies gain more relative weight than larger babies, since the actual increments are the same.

The time of first feed after birth has a greater effect on subsequent progress than has birth weight. In Rank 1, for all measures of loss of weight and the duration of that loss, the late feeding girls and the middle feeding boys had the advantage. In Rank 2+, the middle feeding girls were unequivocally superior to the other groups. The differences were not as striking in the boys, although there was a tendency for the early feeding group to lead. The middle feeding girls and the early feeding boys in Rank 2+ also returned to birth weight soonest, while in Rank 1 both boys and girls of the middle feeding group did best.

When the categories were scored, an interesting pattern emerged (table 3). Second and later born babies could advantageously be fed earlier than first-born babies, and boys could be fed earlier than girls.

A very tentative explanation for these findings may be that Bantu boys recover more quickly from the stress of labor than Bantu girls, and that second and later born babies are less affected than first born babies.

We could find no reference in the literature to the effect of time of first feed after birth on the subsequent progress of the babies. Enquiries at the leading maternity hospitals and nursing homes in Durban revealed that the routine time of first feed after birth varied from three to 12 hours, with no definite reasons given for the time interval chosen. Various obstetric and baby-feeding textbooks in England and America

give time of first feed after normal delivery to be anything between 8 and 24 hours after birth, the reasons being to allow the mothers and babies to recover from the effects of labor. It would appear that investigation in this field is necessary if we are to have any scientific reason for a particular time interval between birth and first feed.

SUMMARY AND CONCLUSIONS

Five-hundred and ninety-eight full term babies, born of normal vertex delivery, who were well during their stay in hospital, were studied with reference to the effect of birth weight and the time of first feed on their progress in the first 10 days of life.

(a) The effect of birth weight was slight.

1. In all ranks heavier babies lost more actual and relative weight than lighter babies, and on the whole for a longer period.
2. In first born (Rank 1), the average babies gained more absolute and relative weight than the light babies.
3. In subsequent births (Rank 2+), the light babies gained most relative weight, although the actual weight gain varied for boys and girls.
4. In all ranks the light girls and the average boys returned to birth weight soonest.
5. The total progress showed that light girls did best in all ranks. Light boys were better off in Rank 1, and average boys in Rank 2+.

However, owing to their superior birth weight, heavy babies still weighed the most on discharge from hospital.

(b) Time of first feed after birth had a greater effect on subsequent progress than did birth weight.

1. In Rank 1, late feeding girls and middle feeding boys lost less weight, and for a shorter period than the other groups, while in Rank 2+, middle feeding girls and early feeding boys had the smallest loss.
2. In Rank 1, middle feeding girls and boys returned to birth weight soonest, while in Rank 2+ middle feeding girls and early feeding boys were superior.

3. The total progress picture showed that second and later born babies could be fed earlier than first born, and boys could be fed earlier than girls.

With the exception of first-born girls, babies were best off being fed within 6 hours of birth.

ACKNOWLEDGMENTS

We again wish to thank Dr. Allan Taylor, Superintendent of the McCord Zulu Hospital, for his courtesy in allowing us the facilities of his hospital, and the Matron and staff of the hospital for their kindness and help in this project.

We would also like to thank the staff of the Hollerith Office, Durban, for their unfailing co-operation.

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APPENDIX 1

Distribution of times of first feed

HOURS AFTER BIRTH	BOYS		GIRLS	
	Rank 1	Rank 2+	Rank 1	Rank 2+
0	21	68	18	68
1	13	25	11	34
2	16	21	7	22
3	7	14	6	28
4	3	14	5	11
5	2	13	4	9
6	2	9	3	9
7	5	10	2	7
8	2	10	5	10
9	1	11	3	8
10	3	10	2	6
11	..	1	2	1
12	..	..	3	..
13	..	1	..	..
14	..	1	..	2
15	1	1	..	..
16	..	..	..	..
17	..	..	..	..
18	..	1	..	..
19	..	1	..	..
20	..	..	..	..
21	..	..	1	..
22	..	1	..	1
27	..	..	..	1

APPENDIX 2 (a)

Mean daily gain or loss in weight in ounces according to birth weight—girls

Rank 1

DAY	6 LB 7 OZ OR LESS NO	MEAN	SD	6 LB 8 OZ-7 LB 15 OZ NO	MEAN	SD	8 LB OR MORE NO	MEAN	SD
1	26	−1.73	1.78	33	−2.89	2.26	6	..	..
2	30	−4.00	1.65	37	−5.58	2.94	6	..	..
3	30	−5.20 (5.4%)	3.48	38	−7.21	5.29	6	..	..
4	30	−5.13	5.21	38	−7.37 (6.4%)	6.77	6	..	..
5	29	−4.86	5.58	37	−6.51	7.87	6	..	..
6	28	−4.07	6.33	36	−5.78	8.70	6	..	..
7	26	−3.46 (−3.6%)	6.64	32	−5.44 (−4.7%)	9.38	5	..	..
8	17	..	..	22	−4.18	10.61	5	..	..
9	13	..	..	15	..	..	3	..	..
10	5	..	..	3	..	..	1	..	..

Rank 2+

DAY	6 LB 7 OZ OR LESS NO	MEAN	SD	6 LB 8 OZ-7 LB 15 OZ NO	MEAN	SD	8 LB OR MORE NO	MEAN	SD
1	41	−2.26	2.03	123	−2.44	2.39	29	−3.40	3.37
2	56	−4.20 (4.3%)	2.69	132	−5.64 (4.9%)	3.27	34	−6.59 (4.8%)	3.21
3	56	−4.04	4.11	133	−5.63	4.61	34	−6.06	4.37
4	55	−2.64	5.63	131	−4.33	5.36	34	−4.47	5.62
5	54	−1.81	6.52	129	−2.84	6.23	34	−3.35	6.73
6	54	−0.44	6.95	125	−1.91	6.89	34	−3.06	7.66
7	46	−0.30	7.42	107	−0.51	7.75	30	−1.47	7.84
8	28	+1.86	8.02	68	+0.53	7.91	17	..	..
9	15	..	..	33	−0.27	7.42	11	..	..
10	7	..	..	11	..	..	4	..	..

10	7	..	..	11	..	..	4	..	..

APPENDIX 2 (b)

Mean daily gain or loss in weight in ounces according to birth weight—boys

Rank 1

DAY	6 LB 7 OZ OR LESS NO	MEAN	SD	6 LB 8 OZ-7 LB 15 OZ NO	MEAN	SD	8 LB OR MORE NO	MEAN	SD
1	25	−2.62	2.39	37	−2.58	3.06	8	..	..
2	27	−5.59	2.23	41	−5.93	3.78	9	..	..
3	27	−6.56 (6.9%)	3.90	41	−8.32	5.16	10	..	..
4	27	−6.26	5.39	40	−8.45 (7.4%)	6.71	10	..	..
5	27	−5.07	5.90	40	−7.60	8.16	10	..	..
6	25	−4.84	5.90	40	−6.05	8.40	10	..	..
7	22	−2.18 (2.3%)	6.05	38	−5.05 (4.4%)	8.94	10	..	..
8	16	..	..	33	−2.76	8.54	8	..	..
9	9	..	..	25	−0.12	8.16	7	..	..
10	5	..	..	10	..	..	3	..	..

Rank 2+

DAY	6 LB 7 OZ OR LESS NO	MEAN	SD	6 LB 8 OZ-7 LB 15 OZ NO	MEAN	SD	8 LB OR MORE NO	MEAN	SD
1	24	−2.00	2.33	116	−2.41	2.29	48	−3.19	2.87
2	28	−4.07	2.73	133	−5.10 (4.4%)	2.60	55	−6.65 (4.9%)	3.25
3	29	−4.38 (4.5%)	3.37	134	−4.70	3.95	56	−6.61	4.64
4	29	−3.69	4.50	133	−3.33	5.62	56	−5.11	5.74
5	29	−2.52	5.27	134	−1.73	6.06	54	−3.59	6.46
6	28	−1.50	5.80	131	−0.65	6.83	55	−1.76	6.65
7	24	−0.33	6.77	109	+0.03	7.55	46	−0.83	6.27
8	15	..	..	70	+1.37	7.82	32	+1.19	5.80
9	8	..	..	31	+2.29	8.45	18	..	..
10	2	..	..	12	..	..	9	..	..

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APPENDIX 3

Total initial loss of weight (in ounces)

	RANK 1						RANK 2+					
	GIRLS			BOYS			GIRLS			BOYS		
	NO	MEAN	SD	NO	MEAN	SD	NO	MEAN	SD	NO	MEAN	SD
Birth Wt Groups												
6 lb 7 oz or less	30	7.00 (7.3%)	3.94	27	8.54 (8.9%)	4.45	56	5.73 (5.8%)	3.56	30	5.70 (5.8%)	3.24
6 lb 8 oz-7 lb 15 oz	38	9.11 (7.9%)	6.07	41	10.13 (8.9%)	6.35	132	7.32 (6.4%)	4.32	134	6.52 (5.6%)	3.86
8 lb or more	6	..	..	10	..	..	34	8.03 (5.9%)	4.93	56	8.16 (6.0%)	4.64
Time of First Feed after Birth												
59 minutes or less	18	..	..	21	10.98	5.47	68	7.87	4.70	68	6.62	3.50
1-5 hours	33	9.05	5.54	41	9.16	6.01	104	6.47	4.12	87	7.01	4.28
6 hours or more	21	7.17	4.31	14	..	..	45	7.23	3.97	57	6.94	4.58

APPENDIX 4

Duration of loss of weight in days

	RANK 1						RANK 2+					
	GIRLS			BOYS			GIRLS			BOYS		
	NO	MEAN	SD	NO	MEAN	SD	NO	MEAN	SD	NO	MEAN	SD
Birth Wt Groups												
6 lb 7 oz or less	30	3.70	1.49	27	3.46	1.14	56	3.00	1.13	30	2.90	1.02
6 lb 8 oz-7 lb 15 oz	38	3.63	1.70	41	3.74	1.30	132	3.09	1.23	135	2.89	1.00
8 lb or more	6	..	..	10	..	..	34	3.12	1.35	56	3.04	.82
First Feed												
59 minutes or less	18	..	..	21	3.98	1.53	68	3.18	1.25	68	2.90	.96
1-5 hours	33	3.99	1.74	41	3.38	1.09	104	2.94	1.12	87	3.02	1.04
6 hours or more	21	3.60	1.51	14	..	..	45	3.23	1.44	57	2.87	.89

6 hours or more	21	3.60	1.51	14	..	..	45	3.23	1.44	57	2.87	.89

APPENDIX 5

Percentage of babies who had regained birth weight by the 7th day

	RANK 1				RANK 2+			
	GIRLS		BOYS		GIRLS		BOYS	
	NO	%	NO	%	NO	%	NO	%
Birth Weight Groups								
6 lb 7 oz or less	30	43.3	27	33.3	56	55.4	30	46.7
6 lb 8 oz-7 lb 15 oz	38	26.3	41	34.1	133	48.9	135	57.8
8 lb or more	6	..	10	..	35	42.9	55	52.7
Time of First Feed After Birth								
59 minutes or less	18	..	21	23.8	68	42.6	68	66.2
1-5 hours	33	39.4	41	39.0	104	55.8	87	54.0
6 hours or more	21	23.8	14	..	45	48.9	57	42.1

APPENDIX 6 (a)

Mean daily gain or loss in weight in ounces according to time of first feed after birth

Girls: Rank 1

DAY	59 MINUTES OR LESS NO	MEAN	SD	1-5 HOURS NO	MEAN	SD	6 HOURS OR MORE NO	MEAN	SD
1	17	..	..	28	−2.57	2.49	19	..	..
2	18	..	..	33	−5.29	2.68	20	−4.85	2.65
3	18	..	..	33	−6.52	4.95	21	−6.02	3.66
4	18	..	..	33	−6.70 (6.1%)	6.70	21	−6.24 (5.6%)	4.51
5	17	..	..	33	−5.55	7.62	20	−5.80	5.31
6	17	..	..	33	−4.82	8.40	18	..	..
7	14	..	..	29	−4.66	9.23	18	..	..
8	13	..	..	17	..	..	12	..	..
9	8	..	..	13	..	..	8	..	..
10	2	..	..	5	..	..	2	..	..

Girls: Rank 2+

DAY	59 MINUTES OR LESS NO	MEAN	SD	1-5 HOURS NO	MEAN	SD	6 HOURS OR MORE NO	MEAN	SD
1	55	−3.06	2.83	90	−2.19	2.55	43	−2.57	1.82
2	67	−5.95	3.31	103	−5.02 (4.3%)	3.34	45	−5.79 (4.9%)	2.43
3	67	−6.16 (5.3%)	4.80	104	−4.67	4.54	45	−5.41	3.87
4	67	−5.00	6.00	102	−2.84	5.33	44	−4.50	4.93
5	66	−3.61	6.84	99	−1.69	6.33	45	−2.91	5.75
6	64	−2.78	7.88	99	−0.64	6.81	43	−2.12	6.37
7	56	−2.18	8.56	87	+0.56	7.47	37	−0.73	6.41
8	32	−0.44	9.18	56	+1.68	7.81	22	0.00	7.74
9	10	..	..	33	+2.52	7.88	15	..	..
10	3	..	..	11	..	..	7	..	..

APPENDIX 6 (b)

Boys: Rank 1

DAY	59 MINUTES OR LESS NO	MEAN	SD	1-5 HOURS NO	MEAN	SD	6 HOURS OR MORE NO	MEAN	SD
1	16	..	..	39	−2.03	3.32	13	..	..
2	21	−6.71	4.20	40	−5.95	3.95	14	..	..
3	21	−8.14	4.39	41	−7.39 (6.6%)	5.18	14	..	..
4	21	−8.33 (7.5%)	4.71	40	−6.80	6.71	14	..	..
5	21	−7.48	5.98	40	−5.95	7.95	14	..	..
6	21	−7.00	6.82	38	−4.89	7.87	14	..	..
7	20	−6.20 (5.6%)	7.55	37	−3.11 (2.8%)	8.33	13	..	..
8	17	..	..	30	−1.73	7.91	10	..	..
9	15	..	..	18	..	..	8	..	..
10	5	..	..	8	..	..	5	..	..

Boys: Rank 2+

DAY	59 MINUTES OR LESS NO	MEAN	SD	1-5 HOURS NO	MEAN	SD	6 HOURS OR MORE NO	MEAN	SD
1	58	−2.97	2.53	74	−2.72	2.94	48	−1.98	1.65
2	68	−5.44 (4.6%)	2.87	84	−5.19	2.95	56	−5.57	2.93
3	69	−5.14	3.58	86	−5.31 (4.4%)	4.15	56	−5.61 (4.7%)	4.60
4	69	−3.38	4.82	85	−4.11	5.82	56	−4.50	5.92
5	69	−1.81	5.35	85	−2.60	6.28	56	−2.82	6.73
6	67	−0.13	6.15	85	−1.19	6.45	55	−2.24	7.44
7	57	+0.82	6.18	71	−0.10	6.96	47	−1.77	8.42
8	37	+3.54	6.49	47	+1.04	6.26	29	−1.62	8.32
9	17	..	..	23	+3.00	6.21	15	..	..
10	9	..	..	8	..	..	5	..	..

Figures in parentheses show percentage of birth weight lost by day of maximum loss; and also, for purposes of comparison, on 7th day where no information is available as to when the group regained its birth weight.

BOOK REVIEWS

Anthropology Today: An Encyclopedic Inventory. Prepared under the chairmanship of A. L. KROEBER, Pages xvi + 966, University of Chicago Press, 1953, $9.00.

An Appraisal of Anthropology. Edited by SOL TAX, LOREN C. EISELEY, IRVING ROUSE, and CARL F. VOEGELIN, Pages xiv + 395, University of Chicago Press, 1953, $6.00.

For two weeks, from 9 to 20 June 1952, some eighty scholars, most of whom were anthropologists, conducted an international symposium on anthropology. The symposium was initiated and held under the generous auspices of the Wenner-Gren Foundation for Anthropological Research. The theme of the symposium was "A World Survey of the Status of Anthropology," and the participants in the symposium were selected not merely as outstanding specialists but also for their ability to synthesize the views of others and for their broad grasp of anthropology in its totality. In planning for the symposium it was suggested that three broad categories be considered: (1) an inventory of modern anthropology, (2) an appraisal of modern anthropology, and (3) a handbook of world resources for research and education in anthropology. It was within this framework of categories that the symposium was conducted. The first and second volumes under review here are the published realizations of the first two categories. Though it is nowhere stated I presume that a third volume, dealing with the third category, will be forthcoming.[1]

Anthropology Today: An Encyclopedic Inventory contains the inventory papers, fifty in number, which were circulated among the participants before the symposium and later presented, though not read, and discussed at the symposium. This volume opens with a valuable preface by the indefatigable Director of the Wenner-Gren Foundation, Dr. Paul Fejos, in which he gives an interesting account of the history of the symposium. This is followed by an introduction from the pen of the doyen of American anthropologists, Dr. A. L. Kroeber, which extends the preface of

[1]This has now appeared: *International Directory of Anthropological Institutions*, Edited by William L. Thomas, Jr., and Anna M. Pikelis, Pages xii + 468, Published by the Wenner-Gren Foundation for Anthropological Research, Inc., New York; Distributed by the American Anthropological Association, Andover, Mass., 1953, $12.50.—Ed.

Dr. Fejos. The second volume, *An Appraisal of Anthropology* contains the reports of the discussions of the inventory papers; it also contains an informative and charming preface by the editors, a very pleasant address of welcome by the founder, Dr. Axel L. Wenner-Gren, and an introduction by Dr. A. L. Kroeber explaining the mechanics of the symposium.

It should be clear that the appraisal volume must be read in conjunction with the inventory volume if the reader is to get anything out of the former—and there is a great deal, indeed, to be gotten out of the appraisal volume. Since the discussions in the appraisal volume follow the seven sections into which the inventory volume is divided the reader will want, every so often, to turn to the appraisal volume for the discussions. I shall confine myself in what follows to an account of the inventory volume and say here of the appraisal volume that it is quite as indispensible reading as the inventory volume, and should on no acount be missed. In many ways it is the more readable and interesting of the two volumes.

The first paper, by Robert F. Heizer, "Long-range dating in archeology," presents an admirable survey of all the known methods of dating the remains of man. Kenneth B. Oakley's "Dating fossil human remains" gives an authoritative account of the fluorine method of dating human remains. In "The strategy of culture history" Irving Rouse discusses the various methods and approaches to the historical reconstruction of cultures. So much for "Methods" under the rubric "Problems of the historical approach."

Under "Results" William L. Straus, Jr. in "Primates" gives us a survey largely of what we don't know about the order of mammals to which man belongs. I found this a most disappointing paper. Surely, here was an opportunity to discuss not only what we do know but the results achieved by the particular methods used. "The idea of fossil man" by Pierre Teilhard de Chardin is not a particularly exciting piece, and Hans Weinert's "Der Fossil Mensch" contains so many errors of fact and so many misstatements, as Dr. W. L. Straus, Jr. points out in his discussion, it had been far better if it had been excluded from the volume. Erwin H. Ackerknecht's paper on "Paleopathology" is a brief and to the point survey of an important subject, while Carlos Monge's "Biological basis of human behavior" is a sadly mistitled paper, for what it deals with are physiological changes in men living at high altitudes. It will, nevertheless, interest those who are unfamiliar with Monge's book on "Trans-Andean Man." Henri Vallois' discussion of "Race" is readable but pedestrian. The next seven papers are masterly:

"Old World prehistory: Paleolithic" by Hallam L. Movius, Jr.; "Old World prehistory: Neolithic" by V. Gordon Childe; "New World culture history: South America," by Wendell F. Bennett; "New World culture history: Middle America," by Alfonso Caso; "New World culture history: Anglo-America," by Alex Krieger; "Historical linguistics and unwritten languages," by Joseph H. Greenberg; and "Style," by Meyer Schapiro.

Under "Theory" there is an excellent paper by Julian H. Steward on "Evolution and process" in social anthropology in which many good points are made, especially that one need not be a believer in unilinear evolution to accept the fact that there has been evolution in human societies. G. S. Carter's "The theory of evolution and the evolution of man" hardly lives up to its promise, for man is virtually completely omitted from Dr. Carter's discussion. J. G. D. Clark's paper "Archeological theories and interpretation: Old World," is excellent, an is Gordon R. Willey's "Archeological theories and interpretation: New World." Duncan Strong's "Historical approach in anthropology," is a most readable and scholarly paper, but it does not seem to me sufficiently critical of the lack of historical dimensionality which American anthropologists have on the whole exhibited.

Under the rubric "Problems of process" Floyd G. Lounsbury contributes a paper on "Field methods and techniques in linguistics" which will be found extremely helpful by field anthropologists with a minimum of training in linguistics, and it will also be found most interesting by the non-specialized reader. There is an excellent discussion of "Psychological techniques: Projective tests in field work" by Jules Henry and Melford E. Spiro and a most invaluable examination of "Interview techniques and field relationships" by Benjamin D. Paul; this latter piece will long form a breviary for all beginning field workers. Similarly invaluable is Oscar Lewis' discussion of "Controls and experiments in field work"; while George P. Murdock gives an interesting account of the work being done by the Human Relations Area Files at Yale in "The processing of anthropological materials." In this paper Murdock refers to most of the relevant work done by others, and thus provides a ready source for the relevant references. In "The contributions of genetics to anthropology," William C. Boyd puts the case for genetics as expertly as he always does, while Clyde Kluckhohn writes a fascinating chapter on "Universal categories of culture," which, as Forde points out, really deals with the determinants rather than with the categories of culture. Claude Lévi-Strauss on "Social structure" is altogether admirable,

while Harry Hoijer's "The relation of language to culture" should be read by everyone interested in the use and possible uses of language. "Structural linguistics" by André Martinet will be of interest only to linguistic students, but Stith Thompson's "Advances in folklore studies" will be of interest to everyone. It would be impossible to speak too highly of A. Irving Hallowell's "Culture, personality, and society"; this is a masterpiece. Ralph Beals' "Acculturation" is an excellent historical account of the development of this new branch of anthropology, the study of culture changes when peoples of different cultures come into contact with one another. Margaret Mead's paper on "National character" is a fundamental piece which all workers in this field will have to read. "Cultural values" by F. C. S. Northrop is a valuable discussion of legal and cultural values, and David Bidney's "The concept of value in modern anthropology" is a stimulating paper, which is written from the viewpoint of a philosopher with a very scholarly background in anthropology. Of a totally different kind is Marston Bates' admirable paper on "Human ecology"; this is written from the viewpoint of the zoologist interested in man. "The strategy of physical anthropology" by S. L. Washburn is another stimulating paper by one of the most active of physical anthropologists. Robert Redfield's "Relations of anthropology to the social sciences and to the humanities," is an excellent and pivotal paper, which makes a bold and eloquent plea to anthropologists to re-survey themselves in the human situation.

"Problems of application" provides a well rounded discussion of the usefulness of physical measurements in non-traditional situations and for non-traditional purposes. "Growth and constitution" by J. M. Tanner presents an excellent survey, but omits reference to prenatal growth and constitution—a most important aspect of the subject, without the understanding of which postnatal growth and constitution cannot be properly understood. "Applied anthropology in medicine" by William Caudill provides an overall survey of the part that the applied anthropologist has been playing and can play in the future in medicine. Mary R. Haas' "The application of linguistics to language teaching" does what it says very clearly, and in "Applied anthropology in industry" Eliot D. Chapple gives a most interesting account of this important branch of anthropology. The next four papers, each written by an expert, are the best short surveys of their kind to be found anywhere of applied anthropology in government. Edward A. Kennard and Gordon McGregor deal with the United States, Daryll Forde deals with British Africa, G. Jan Held with the Netherlands, and Alfred Métraux with the United Nations.

In a final paper John Howland Rowe deals with "Technical aids in anthropology: a historical survey," which is not only very extensive in its survey but also very stimulating in its criticisms and suggestions. There is a list of contributors and an index.

So much for the formal annotation of the contents of the volume, a volume which will long constitute a landmark in the history of anthropology. This stocktaking of the present status of anthropology and the direction in which it is considered by these various authorities it should travel will constitute a fountain from which many will drink deep and heady draughts in the years to come. We all owe a very profound debt of gratitude to the Wenner-Gren Foundation for having made this stocktaking possible and for having made it available with such grace and expedition.

The organization of the symposium was a task presenting many difficulties; so far as was humanly possible that task seems to have been carried off consummately well. It is in no spirit of the carping critic therefore that I venture to make the following remarks. I hope they are not altogether the product of my own private prejudices.

Although anthropology as a scientific discipline is little more than half a century old its development, indeed, one might say its proliferation, has been rapid. The subject already has an extremely interesting history—it would have been pleasant to see that fact recognized at the symposium by the devotion of a separate inventory paper dealing with the history of anthropology.

It would also have been of great interest to have had an historical and analytic paper on the relations of anthropology to literature, to the novel, poetry, the drama, and criticism. One is led to believe that anthropology has had a much wider influence upon the modern world than even many anthropologists realize.

Finally, I should very much have liked to see a paper on the training of the anthropologist—surely, a unique opportunity was missed here.

It is possible that all these matters were considered by the planners of the symposium and for various reasons found impracticable of realization. Opportunities for the discussion of these matters will, no doubt, be afforded at some future time.

I must confess that while I found Professor Vallois' paper on "Race" good, it seemed to me rather heavily academic and not sufficiently concerned with the everyday realities of the situation. This is a besetting sin of many anthropologists who when they speak of "race" speak of it as if it were an abstraction, and too many of them, I am afraid, when

they speak of the Negro speak of him, too, as if he were an abstraction. Doubtless Professor Vallois was limited by his instructions, as I have said, his paper is good enough as far as it goes. What one misses is a presentation, in summary form of course, of the work which has been done in recent years in so many different fields relating to the problems of race prejudice, its genesis and development, and the various means which have been utilized to obviate or reduce its development. It seems to me that such an inventory paper and its discussion would have been most useful. During the last fifteen years we have made great progress in understanding the nature of race prejudice, and we have already had the opportunity to evaluate some of the methods of handling it. I refer to changing attitudes in the home, direct and indirect education, community measures, and legal ordinances, not to mention more general legislative measures.

It is interesting to recall here that not so long ago many pundits were asserting that "you can't legislate race prejudice out of existence." Well, astonishingly enough, we have seen legislative measures operating in the most substantive of ways not only to control the expression of race prejudice but also to reduce its virulence. And this, not merely by inhibition but by making it possible for people freely to mingle with one another where formerly they were enjoined by custom not to do so. The application of anthropological understanding to the solution of race problems might surely have found a legitimate place in the symposium. "Race" is one of the most pressing issues of the day, and the anthropologist, surely, has much to contribute towards the intelligent and effective meeting of that issue.

One thing becomes very obvious as one reads paper after paper as well as the discussions of these papers; namely, that anthropologists for the most part still lack an historical sense. Apart from Strong's paper there are scarcely any references to this important subject. Historical reconstruction as a method is more than ordinarily difficult when studying simpler cultures, but that is no reason why it should be treated as impracticable. Every culture is a product of a long history, and it should be the task of the anthropologist, among other things, to discover something of the nature of that history. The historical approach is most effectively realized by the archeologist, but this is an approach which is forced upon him, for archeology deals with cultures which are either extinct or no longer in existence in the form in which he recovers them. What we need is the application of the historical method to living cultures and not merely a broad overall approach to the history of

human culture as a whole. I regret to say that there seems to be little evidence that we shall get it. But enough of this.

Anthropology has come into its own. It now has to come into others. It has already made more than a beginning, as these two noble volumes most abundantly testify. No educational institution worthy the name of a college should be without its department of anthropology; nevertheless there are a number of major institutions without such a department, and numerous colleges are completely without any teaching in the subject. This is the more of an anachronism because anthropology should be the central core of education and therefore of the organization of the college curriculum. However, since this is scarcely recognized in those institutions in which a department of anthropology exists, it is perhaps a little too much to expect that a college education be built around a knowledge of anthropology.

Because anthropology is the science and art of humanity it stands in a pivotal position in relation to all other human knowledge. A truly liberal education should be first and foremost in humanity, and this no subject is better able to provide than anthropology. It is the subject about which and from which a truly integrated education could be developed, and it is my hope that this will some day be undertaken as a pilot study by some farseeing college administration. Meanwhile, the two volumes I have so inadequately discussed in this review should afford every stimulus to those engaged in the field of anthropology as well as to those who are interested in it to bring about this much to be desired change.

M. F. Ashley Montagu

BOOKS RECEIVED

Streptococcal Infections. Edited by Maclyn McCarty. x + 218 pp. Columbia University Press, New York, 1954. $5.00.

Contributions to the Anthropology of the Caucasus. By Henry Field. x + 154 pp. Papers of the Peabody Museum, Harvard University, Cambridge, Massachusetts, Vol. XLVIII, No. 1, 1953. $6.50.

Catalogue des Hommes Fossiles. Edited by Henri V. Valois and Hallam L. Movius, Jr., XIX Congrès Géologique International, Alger (1952), pp. 63-378, 1953.

Music Therapy. By Edward Podolsky. xii + 335 pp. Philosophical Library, New York. 1954. $6.00.

INFORMATION FOR CONTRIBUTORS

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Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the publication has been returned to the press.

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WAYNE UNIVERSITY PRESS, *Publishers*

DETROIT 1, MICHIGAN, U. S. A.